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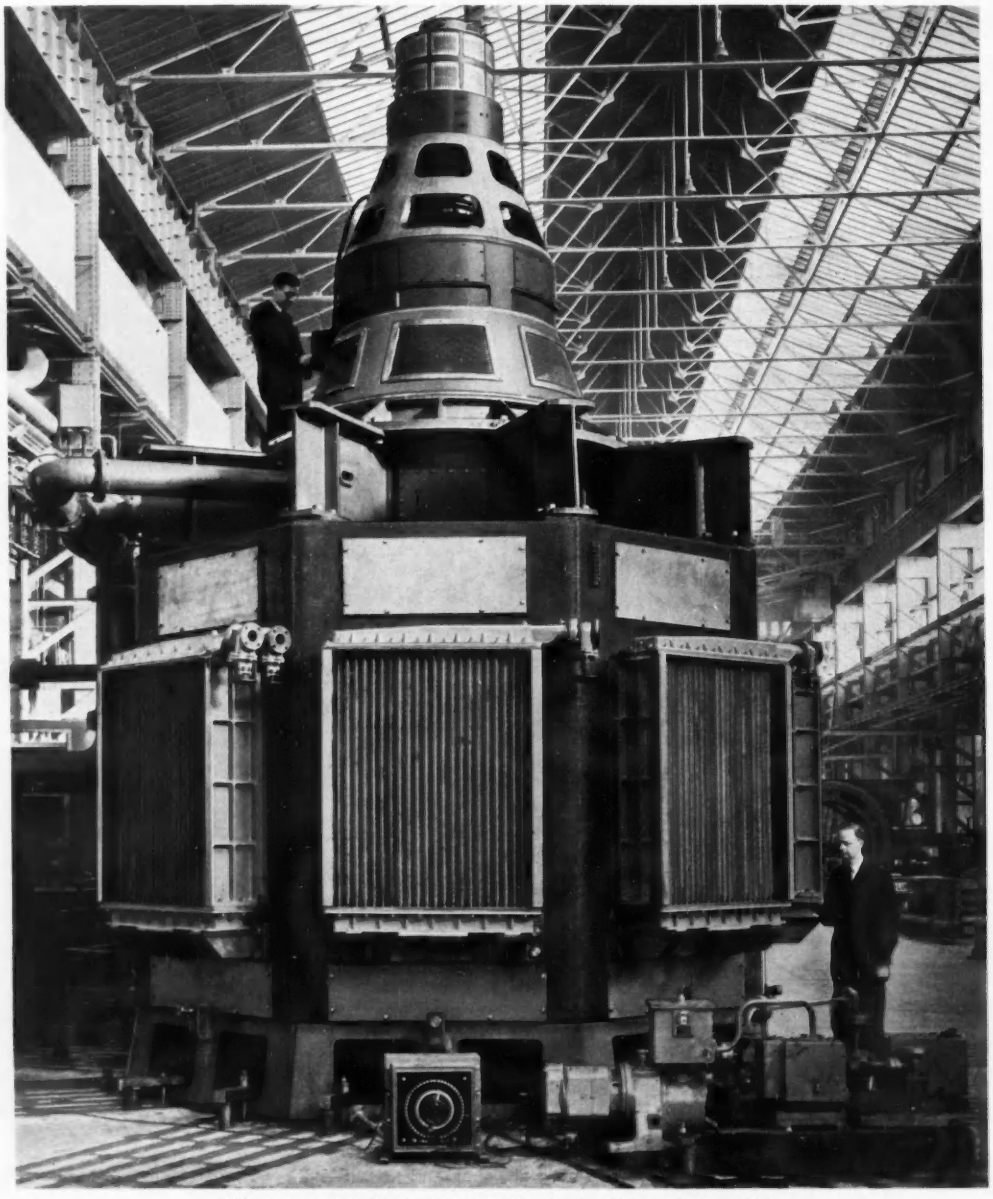


HYDRO-ELECTRIC ALTERNATORS FOR TASMANIA.

The first of five 25 MW, 11 kV, 600 r.p.m. vertical shaft alternators for the Tasmania Hydro-Electric Commission on test at Witton Engineering Works.

Progress and Development, 1952

(1) Power Equipment

In the following pages the progress and achievements of the G.E.C. during 1952 *are surveyed. Within the space available it is possible to refer only briefly to the many new developments within the wide range of the Company's activities. Each section is now presented under its own distinctive heading which, it is believed, will make for easy reading and quick reference.*

TURBO-GENERATORS AND COMPRESSORS.

The heavy demand for power plant continues, and during the year under review additional orders have been received from the British Electricity Authority for a further 240 MW of turbo-alternators. These orders include two 30 MW, 11·8 kV sets for Barony Power Station, Ayrshire. This station is of interest, being the first in a new programme in which some B.E.A. sets will be erected at the pitheads to use low-quality coal unsuitable for distribution, but quite suitable, after preparation, for raising steam in modern boiler plant to drive turbo-alternators. Three 60 MW, 11·8 kV hydrogen-cooled sets have also been ordered, two for Hams Hall C and one for the new station at Ince, which will bring the number of sets for these two power stations up to five and four respectively.

In all, fifteen hydrogen-cooled turbo-alternators of this capacity are now in hand, the first of which, seen on test in fig. 1, has recently been commissioned at Uskmouth Power Station, Newport, Mon., where six sets are to be installed. Two 30 MW air-cooled sets have been commissioned at the Huncoat Power Station, one of these being shown in fig. 2.

The installations at these two power stations are noteworthy as regards the system of automatic boiler control employed. In both instances, the boiler house auxiliaries operate in conjunction with grid-controlled rectifiers and are controlled in such a manner that the relationship between air and fuel is consistently maintained at the right value for maximum combustion efficiency. The boiler house control board at the Huncoat power

Fig. 1.—The first of six 60 MW, 11·8 kV hydrogen-cooled alternators for the Uskmouth Power Station on test.

Fig. 2.—One of the two 30 MW, 11·8 kV turbo-alternators at the Huncoat Power Station, Accrington. The eventual complement of this station will be four sets.

station is shown in fig. 3. The two systems vary somewhat in detail and are referred to more fully in the section dealing with rectifiers on page 14. Other features of interest peculiar to the 60 MW sets at Uskmouth are the supervisory equipments for indicating shaft distortion and rotor temperature. The former has been described fully in an article in an earlier issue of this Journal,* and it will be recalled that measurements of shaft distortion are made electromagnetically and recorded continuously so that any irregularities in operation are detected immediately. The method of recording rotor temperature is based on temperature measurement by resistance. The ratio of rotor voltage and rotor current is indicated by a slow speed motor-driven rheostat which, under the control of a suitable magnetic amplifier and relay, is used in a self-balancing circuit. The method of operation ensures that temperature indication is

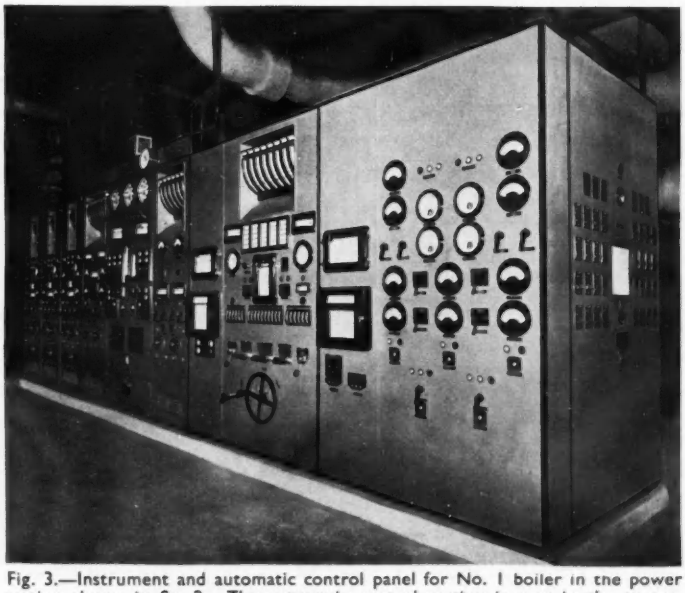


Fig. 3.—Instrument and automatic control panel for No. 1 boiler in the power station shown in fig. 2. The automatic control section is seen in the centre.

* "Supervisory Equipment for the Indication of Shaft Distortion in Steam Turbines," by D. ANTRICH, R. K. HILTON and H. W. B. GARDINER, *G.E.C. Journal*, Vol. XIX, No. 3, July, 1952.

not affected by fluctuating load, the automatic voltage regulator or transients of short duration.

For the Woolwich Power Station the fourth 30 MW, 22 kV turbo-alternator is now in service and a fifth set of this rating is on order.

Among the process steam installations recently ordered is a 1·75 MW, 6·6 kV pass-out/back pressure geared turbo-alternator for the Midland Tar Distillers, Ltd., Oldbury, the pass-out pressure being 125 lb./sq. in. gauge and the back pressure 25 lb./sq. in. gauge; also a geared 7·5 MW, pass-out/condensing turbine for coupling to three existing D.C. generators at the paper mills of Albert E. Reed. This turbine will operate ultimately with steam at 600 lb./sq. in. gauge, 800 degs. F., and when installed will bring the total capacity of G.E.C. plant in the two mills at Aylesford to more than 37 MW. Also for industrial use there is a 2·5 MW, 3·3 kV geared set for Stewarts and Lloyds, Ltd., Bilston.

From overseas, the demand for generating plant is no less heavy, and recent contracts received cover three 30 MW, 11 kV turbo-alternators for the new Kelvin Power Station, Johannesburg. This order brings the total capacity of generating plant in service or in hand for this Municipality alone up to 547·5 MW. Also on order for South Africa is a 60 MW, 11 kV set for the Wilge Power Station of the Electricity Supply Commission. This station, in the Kendal district of the Transvaal, is being built to supply the power required for the development of uranium deposits in the Witwatersrand Gold Mines and to augment the supply for gold mining and industrial purposes generally. The turbine will be operated by steam at 600 lb./sq. in. gauge, 850 degs. F. and the alternator will be air cooled. For the Electrical Trust of South Australia an order is in hand for two 1·2 MW, 2·2 kV geared sets for the Port Lincoln Power Station .

During the period under review generating plant commissioned or in course of erection overseas totals 150 MW. At the Orlando Power Station, Johannesburg, the fifth 37·5 MW set is now in service ; a view of the station showing the five turbo-alternators is seen in fig. 4. Also in South Africa the installation of two 2 MW, 2·1 kV alternators for the Vryheid Colliery has been completed and a 7·5 MW set is in course of erection at Bloemfontein ; orders for two further sets of this rating are in hand.

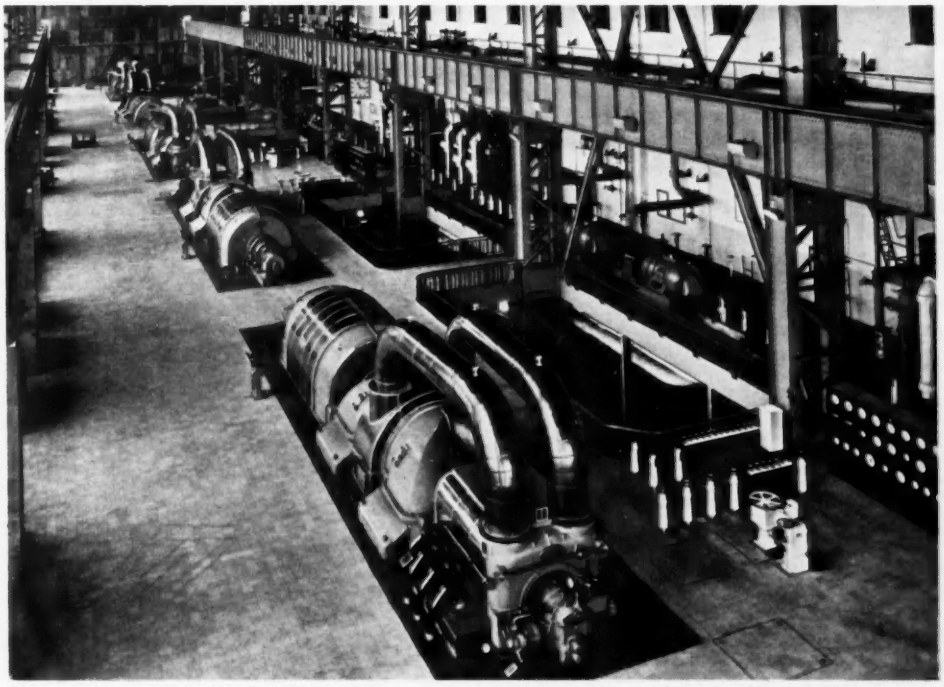


Fig. 4.—Five 37·5 MW, 11 kV turbo-alternators in the Orlando Power Station of the Municipality of Johannesburg. A further five 30 MW sets are on order for this station.

Two 7·5 MW sets are now running in the Howard Generating Station, Wide Bay, Queensland, and a third alternator of this rating has been shipped. For the Haifa Power Station of the Palestine Electric Corporation a second 30 MW, 11 kV unit has been commissioned, and two 20 MW, 10·5 kV sets are now in service in the new peat-burning power station at Allenwood, Eire. Each of the latter alternators is designed to give its rated output at any voltage from 9·5 kV to 11·5 kV and to generate 70 per cent of its MVA output at zero power factor leading. Because of local system conditions a short circuit ratio of 0·75 at normal voltage was specified. This is higher than is customary and to meet this requirement and the considerable voltage regulation, the air-gap is correspondingly larger. Power plant commissioned and in course of erection in India includes two 10 MW, 6·6 kV alternators for the Kalyan Power Station, and one 2 MW, 11 kV geared set for the Government of Orissa Cuttack Thermal Scheme.

Turbine-driven blowers for blast furnaces have been ordered for several iron and steel works: one being for the Redcar Iron Works of Dorman, Long & Co., Ltd. and two for steelworks in Scotland for Bairds & Scottish Steel and for Colvilles, Ltd., the latter having an output of 90,000 cu. ft. of air per min. at 32 lb./sq. in.

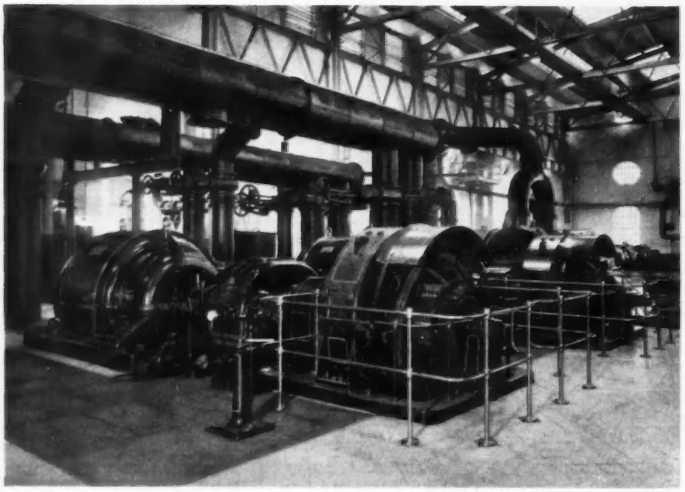


Fig. 5.—Two turbo-blowers at the Park Gate Iron & Steel Co. Ltd. Each is driven by a 2,200 h.p. variable speed D.C. motor supplied from grid-controlled rectifiers.

The two turbo-type blowers for blast furnaces at the Park Gate Iron & Steel Company Ltd., Rotherham, are now in operation (fig. 5). Each has an output of 30,000/25,000 cu. ft. per minute at 10/15 lb. per sq. in., and is driven through speed increasing gears by a 2,200 h.p. variable speed D.C. motor. The variation in speed necessary to ensure blower operation at maximum efficiency at all loads is obtained by controlling the power supplied to the driving motor by means of grid-controlled rectifiers with additional anodes for supplying the motor fields. Further details of this installation are given in the section of this article dealing with mercury arc rectifiers.

All the machines ordered for the integrated scheme at the power house of the Steel Company of Wales at the Margam Works have now been put into commission, bringing the total plant installed since the war to three turbo-type

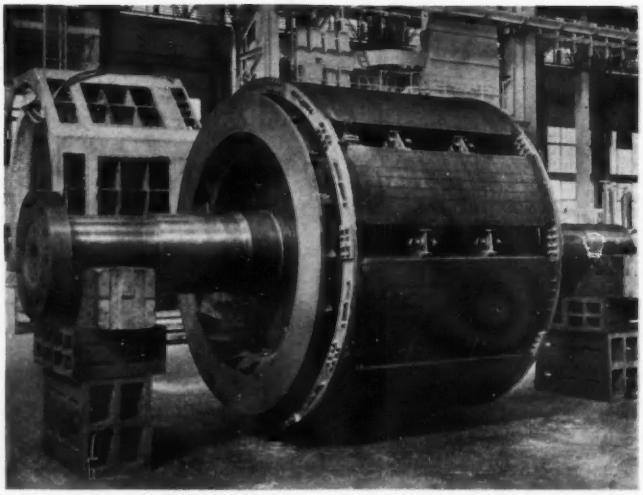


Fig. 6.—The magnet wheel for one of the 25 MW vertical shaft alternators for the Tasmania Hydro-Electric Commission.

blowers, two of 90,000 c.f.m. capacity and one of 60,000 c.f.m. capacity; two 8,000 kW turbo-alternators and one 2,000 kW double pass-out/back pressure turbo-alternator.

In South Africa, eight synchronous motor-driven geared compressors have been erected and brought into service during the past twelve months. Of these, two are for the Anglo-American Corporation and two for the Union Corporation; each is driven by a 4,485 h.p. motor and delivers 20,000 c.f.m. at 100 lb./sq. in. gauge. The remaining machines are each driven by 3,400 h.p. motors and deliver 15,000 c.f.m. at 100 lb./sq. in. gauge; two being for New Consolidated Goldfields, Ltd., and two for Strathmore Investments, Ltd.

Control of Alternators.

In the Progress Article in this Journal, January, 1952, reference was made to the voltage stabiliser (fig. 8), which had been developed for the Ministry of Supply for 10 kVA and 15 kVA machines. It will be recalled that this equipment serves the dual purpose of exciter and voltage regulator and is completely devoid of any moving part or valves. Originally each stabiliser had to be matched individually with the alternator to be controlled, but these units can now be constructed so that they are interchangeable for machines of the same rating. This has been made possible as a result of exhaustive tests to establish the maximum tolerances which can be permitted without adversely affecting operation, and producing the various component parts within these limits. Apart from the advantage of interchangeability, testing is simplified as there is no need for prolonged tests to match each stabiliser with its own alternator.

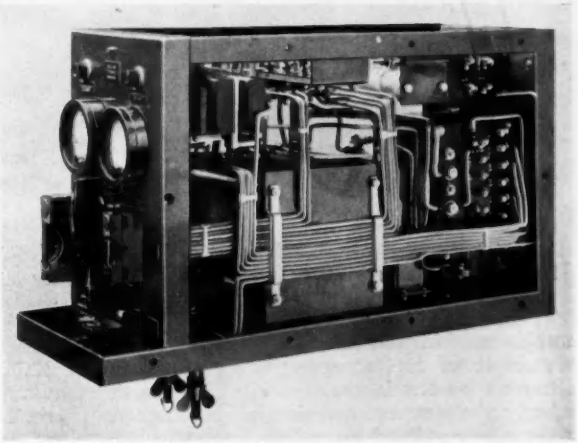


Fig. 8.—Voltage stabiliser with covers removed to show the arrangement of the components.

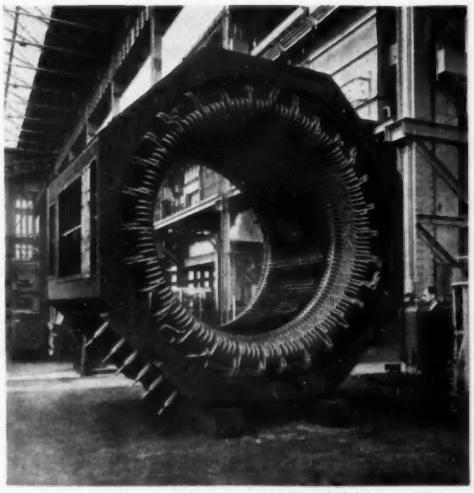


Fig. 7.—The stator for one of the 25 MW vertical shaft alternators.

Hydro-Electric Plant.

In connection with a new aluminium plant now under construction at Sunndalsora, additional hydro-electric plant is to be installed at Aura Kraftonlegg. For this project a contract has been received from the Norwegian State Power Co. for a 50 MW, 12·3 kV, 428·6 r.p.m. horizontal shaft alternator for coupling to an Escher Wyss Pelton wheel. This will be one of the largest horizontal shaft hydro-electric sets in Europe and the physical dimensions of the machine will exceed anything previously built at the Witton Engineering Works. The alternator will weigh over 310 tons, the rotor alone accounting for about 170 tons. Transport difficulties are such that no part must exceed 55 tons in weight and for this reason the machine will be specially designed and constructed so that it can be shipped in sections and erected on site. Two 2·3 MW and a 400 kW hydro set are also on order for this power company.

For the Hydro-Electric Commission of Tasmania, an order for the fifth 25 MW, 600 r.p.m. vertical shaft alternator has been received for the Tungatinah Power Station. The first of these

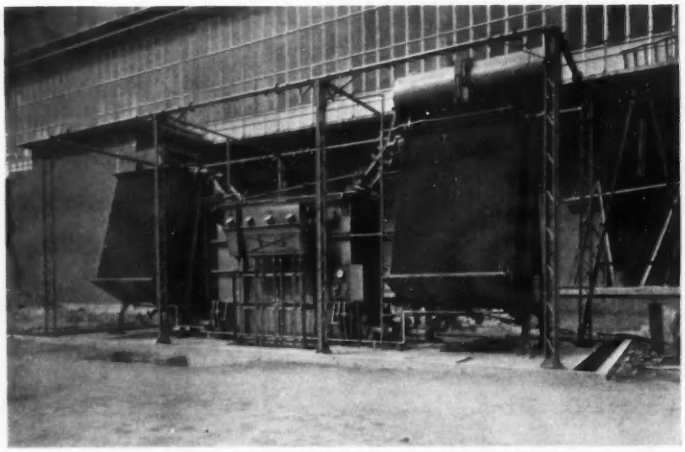


Fig. 9.—One of the 40·5 MVA 11/36kV generator transformers recently commissioned at the Huncoat Power Station.

machines, which has now been shipped, forms the subject of the frontispiece which shows the alternator on test in the Works, The magnet wheel and stator are illustrated in figs. 6 and 7.

TRANSFORMERS.

In the course of the year just ended orders have been received for numbers of power transformers of the largest size. Contracts for the British Electricity Authority include five 45 MVA transformers with voltage ratios of 132/66 kV and 132/33 kV as well as seven generator-transformers for Hams Hall C, Doncaster and Huncoat Power Stations. The three for Hams Hall are each rated at 72 MVA, 141·6/11·8 kV, the two for Doncaster at 36 MVA, 70·8/11·8 kV, and those for Huncoat at 40·5 MVA, 33/11 kV, a similar unit recently commissioned at this power station being shown in fig. 9. Also on order are two 10 MVA, 132/3·45 kV units for Hams Hall and four 120 MVA, 275/132 kV auto-transformers. A voltage range of plus and minus 15 per cent on the 132 kV side is provided by means of on-load voltage regulators. For the Ministry of Supply an order is in hand for thirty 1,500 kVA, 11 kV/415 volt transformers with class "A"

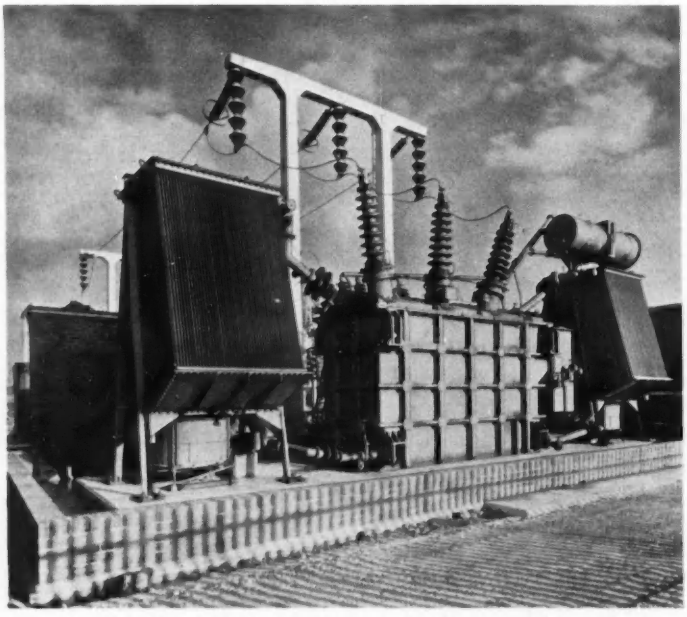


Fig. 10.—45 MVA 132/33 kV transformer at the Oldbury outdoor substation.

insulation throughout and arranged for natural air-cooling.

Several 45 MVA transformers for the British Electricity Authority have been commissioned or are in course of erection on site, including units at Cheltenham, Swindon and Oldbury, the last mentioned being shown in fig. 10.

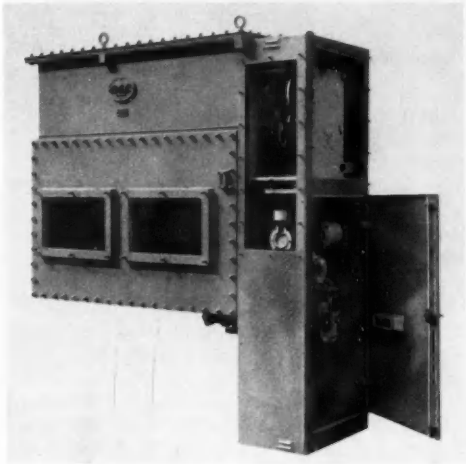


Fig. 11.—Tapping switch, type N, with covers removed to show the contactors and operating mechanism.

Of the many orders received from overseas customers, mention may be made of that placed by the Electric Corporation of Nigeria, covering twenty-two transformers, sixteen of which are rated at 600 kVA and six at 330 kVA. The two 1,200 kW rectifier transformers for the Estoril Railway at Lisbon are now on site. A point of interest is that one of these transformers has its primary winding connected in star while the primary winding of the second unit is connected in delta, so that by connecting the two together through a 300 cycle interphase transformer, the necessary phase displacement is obtained for 12-phase operation of the equipment at 2,400 kW. Another overseas order nearing completion covers fifty-four 200 kVA and forty 600 kVA distribution transformers for Whitehall Securities Ltd. These units are fitted with off-circuit tapping switches and are designed for a low-temperature rise for operation in the tropics.

Transformer Tapping Switches.

The new design of type N switch, of which mention has been made in earlier reviews of progress, is now in full production. This switch (fig. 11), is designed for use with 33 kV transformers ranging from 10 MVA to 20 MVA. It has a current rating of 400 amps. and provides 15 ratios.

Two new designs of switch, designated the type O and type P respectively, have been developed, and prototypes are shortly to be subjected to life tests. The type O switch is for service with 33 kV transformers up to 7·5 MVA capacity, while the type P equipment has been designed for use with 11 kV transformers with ratings up to 3 MVA. In designing these switches, the opportunity has been taken to standardise components, many of which are common to both switches, so that the number of stock parts held in store is reduced and speed of production improved.

Square Wave Transformers and Their Use in the Static Control of Mercury Arc Rectifiers.

Grid control of mercury arc rectifiers is effected by altering the timing of the voltage impulses applied to the grids. In the latest electro-magnetic circuits which have been developed, this is accomplished by using a static phase shifting device in conjunction with a "square wave" transformer. The new design of "square wave" transformer makes the maximum use of the active material thus enabling a compact unit to be made which will produce

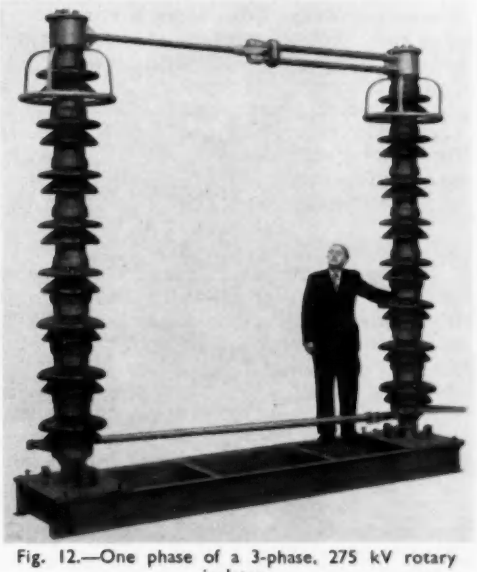


Fig. 12.—One phase of a 3-phase, 275 kV rotary isolator.

very steep fronted grid impulses of any required duration, but usually 60 electrical degrees.

Essential features of the static phase shifting device are :

1. Rapid response to the control signal thereby ensuring stability when used in closed loop control systems.
2. Phase shift over the wide angle of control which may be necessary to give the required variation in the output of a rectifier, especially where the full range from rectification to inversion is involved.

It is to be noted that the problem of static phase shift control has been solved by making use of long distance A.C. transmission line theory. An article dealing fully with this subject appeared in the October 1952 issue of the *G.E.C. Journal*.

OUTDOOR SWITCHGEAR.

Erection of the equipment at the outdoor substation at Oldbury is well advanced. This substation is of the extensible type and, for the first part, three 132 kV, 2,500 MVA oil circuit breakers, isolators, control boards, as well as two 45 MVA transformers, are being installed.

Of the developments in outdoor airbreak switchgear the most outstanding is the production of the new 275 kV isolators and earthing switches; a single-phase isolator is shown in fig. 12. The isolator is rated at 1,200 amps., the three phases being ganged together and operated hydraulically with provision for emergency manual operation. The isolator is of the rotary type with a central single break, the design of the contacts being such that shattering of ice formation is certain. An earthing switch can be fitted on either or both sides of the isolator and is operated by hand, a torsion bar serving to balance the weight of each switch arm. Both the isolators and earthing switch will carry the through short circuit current corresponding to 7,500 MVA.

METALCLAD SWITCHGEAR.

During the year a very considerable amount of 33 kV heavy duty metalclad switchgear has been commissioned or is in course of erection on site, including thirty 750 MVA units for the London and Midlands Electricity Boards, and forty-one 1,000 MVA units for service in Australia. Of these, twelve have been commissioned in the Pyrmont " B " Power Station, Sydney, where a 28 unit board of this type and rating has been in service for several years.

Of the fourteen 11 kV, 1,000 MVA double busbar units being supplied to the new Nechells Power Station, Birmingham, the first six are installed. This switchgear is rated at 4,000 amps., one of the circuit breakers which weighs 4½ tons is shown in fig. 13. Busbar selection is by means of motor-operated oil-immersed switches arranged for both " on " and " off " load selection. A feature of the switchgear is the use of a central gangway which on one side gives access to the back of the circuit breakers and on the other side to the voltage transformers.

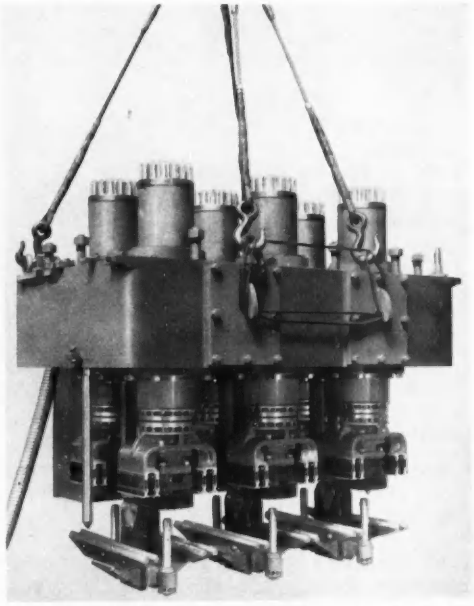


Fig. 13.—11 kV, 4,000 amp. circuit breaker for the 1,000 MVA switchgear at Nechells Power Station, Birmingham.

Many orders have been received for this class of switchgear for service at home and overseas, including a ten-panel 11 kV, 750 MVA board for West Bank Station No. 2, South Africa, and a nine-panel board of the same rating for the ISCOR Works of the South African Iron and Steel Industrial Corporation Ltd., where, it will be recalled, some eighty-seven metalclad units and three electrically-driven turbo-blowers were commissioned about two years ago.* For the British Electricity Board nine 33 kV, 750 MVA units are being built in addition to thirty-eight medium duty units for 6·6 kV and 11 kV service in various substations.

The range of heavy metalclad switchgear has been extended to include non-phase separated

* " Equipment at a South African Steel Works : An Installation at the ISCOR Works, Vanderbijl Park, of the South African Iron and Steel Industrial Corporation, Limited," *G.E.C. Journal*, Vol. XIX, No. 2, April, 1952.

units which can be supplied for the following ratings.

kV	MVA	Current Ratings Amperes				
22	500	400	800	1200	—	—
	750	400	800	1200	1600	2000
	1000	—	800	1200	1600	2000
33	750	400	800	1200	—	—
	1000	400	800	1200	1600	2000

For many years one of the principal features in the design of the Company's heavy metalclad switchgear has been the adoption of complete phase-segregation. This form of construction is still considered desirable in switchgear for important power stations and primary substations, but it is recognised that there are many situations where the use of a simpler construction is justified and it is for this reason that the non-phase separated type of unit has been developed. The units are similar in general construction and appearance to the well-established phase-separated switchgear and possess the recognised advantages associated with that gear. The main simplification is the enclosing of all phases of the busbar structure in a common housing, while it has also been possible to reduce the overall dimensions. A typical unit undergoing a 200 kV impulse test in the Company's 2½ million volt Laboratory is shown in fig. 14. Over 300 units of this type are being built for the Southern Section of British Railways in connection with the frequency changeover in the London area.

Relays.

Several notable additions have been made to the range of relays and protective apparatus produced by the Company.

Standby Earth-Fault Protection Relay.

This relay, type T.D.E. (fig. 15), has been developed for use in standby earth-fault protection schemes. It embodies an induction movement and has a long range time delay. The relay is normally operated from a current transformer in the neutral-to-earth connection of the power system, and provides ultimate earth-fault protection as well as affording thermal protection to such short time rated apparatus as earthing transformers and earthing resistors. It has a fixed setting of 20 per cent of the rated current of the associated current transformer, while the time-setting range is adjustable between 0 and 30 seconds, the basic time setting being that obtained when a current equal to five times the setting current is applied to the relay. An auxiliary element with two separate pairs of contacts is incorporated in the relay for connecting to the appropriate external circuits, and operation is indicated by a flag.

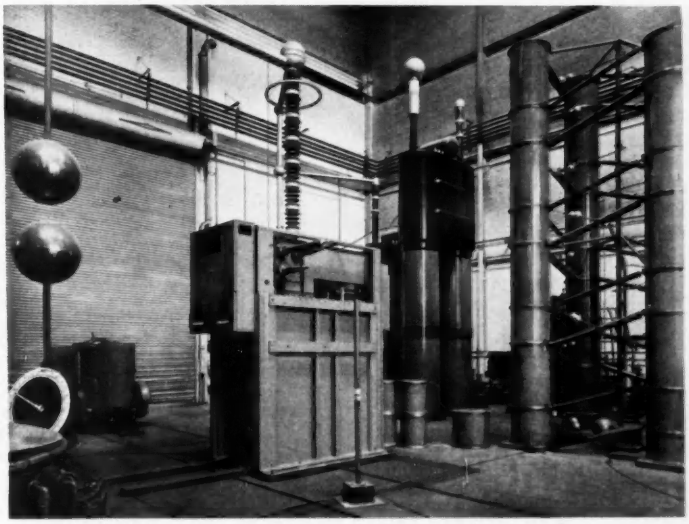


Fig. 14.—A 33 kV heavy metalclad switch unit, non-phase-separated type, set up for a 200 kV impulse test.

Motor Protective Relays.

A range of relays has been produced for use with A.C. induction motors. These relays are available to give combinations of the following :

(*a*) Thermal elements to provide protection against overloads and single-phasing.

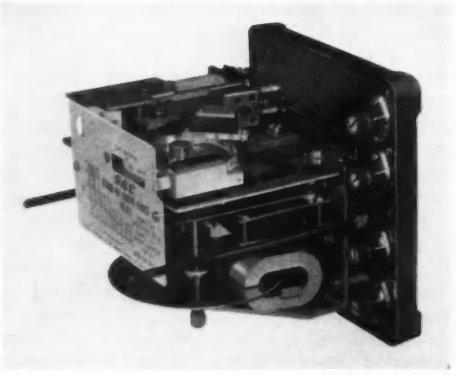


Fig. 15.—Standby earth-fault relay, type T.D.E., with cover removed.

(*b*) Instantaneous electromagnetic elements for short circuit or earth-fault protection.

(*c*) Associated auxiliary tripping and indicating elements.

These relays can be supplied in two standard forms, namely type H and type HST/AM. The type H relay is provided with thermal elements only and may be fitted with auxiliary elements to give separate indication of overloads or single-phasing. It is suitable for use with motors having starting times up to 15 seconds, and where short-circuit protection is afforded by external means such as H.R.C. fuses.

In the type HST/AM relay, the thermal elements are supplied through a small saturable transformer, while an instantaneous over-current element, auxiliary and tripping elements are incorporated. In addition an earth-fault element can be provided. This relay will afford complete protection of the motor against overloads, single-phasing, short circuits or earth faults, the operation of each fault being indicated separately. It is suitable for use with motors having any value of starting time. On the thermal overload protection scale a pointer, which is attached to the moving contact, gives a continuous indication of the load on the motor. The following are the standard settings.

Thermal overload protection setting range : 50 to 150 per cent.

Single-phasing protection against any unbalance over 12 per cent when the motor is running on full load.

Instantaneous short-circuit protection setting range : 800 to 1,600 per cent.

Instantaneous earth-fault protection setting range : 10 to 40 per cent.

BIASED DIFFERENTIAL PROTECTIVE SYSTEMS.

Biased differential protective schemes are now widely used for the protection of generators, transformers and feeders, and are being installed in power stations for transformers having a voltage ratio of 132 kV/3·3 kV. In one instance, where the neutrals on both the 132 kV and 3·3 kV sides of the transformers are solidly earthed, the system of protection used embodies phase-fault elements and separate 132 kV and 3·3 kV earth-fault elements. The transformer is rated at 10 MVA with a tap-change range of $\pm$ 10 per cent and a 10 per cent reactance. The protective scheme provides the following performance.

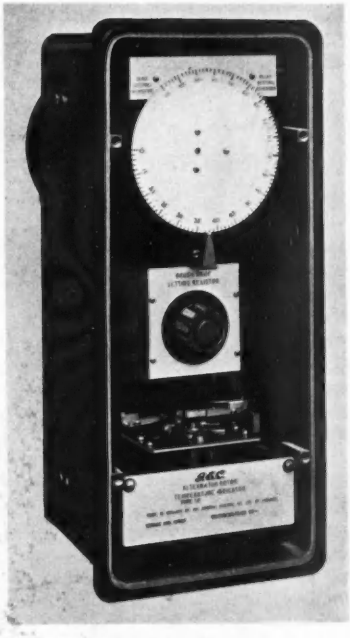


Fig. 16.—Alternator rotor temperature indicator, type T.R.

Type of Fault.	Fault Setting % of rated current of the transformer.	Operating time secs.
132 kV Earth-Fault	60	0·03
3·3 kV Earth-Fault	50	0·03
132 kV Phase-Fault	60	0·1
3·3 kV Phase-Fault	60	0·1

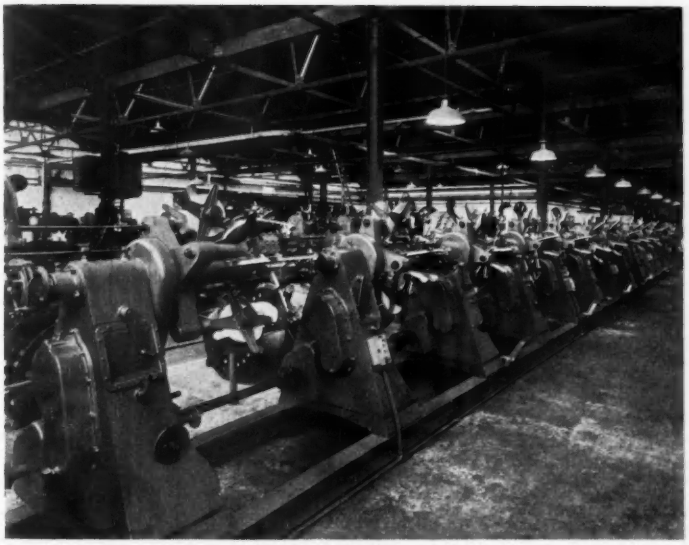


Fig. 17.—Paper lapping machine at Pirelli-General Cable Works for insulating oil-filled cable up to and including 301 kV.

ROTOR TEMPERATURE INDICATOR APPARATUS.

Reference has already been made in this article to temperature indicators for alternator rotors. For this apparatus a transductor-operated differential relay and motor-operated indicator (fig. 16) have been developed, the two units being housed in a case arranged for mounting on the switchboard. The equipment possesses the following advantages:

(*a*) Stability : The indicator does not respond to any violent fluctuations of the exciter voltage, but takes up a position corresponding to the actual temperature of the rotor winding.

(*b*) On full load and overload, where correct indication is most important, the accuracy is at its highest, being within $\pm$ 1 per cent.

(*c*) Variation of the auxiliary voltage supply or of ambient temperature does not affect accuracy, suitable compensation being provided.

(*d*) There are no delicate components, both the relay and the motor-driven indicator being particularly robust.

301 kV OIL-FILLED CABLE.

From the Aluminium Company of Canada an order has been received by Pirelli-General Cable Works covering the manufacture and installation of a 0·4 sq. in., single conductor, oil-filled cable and sealing ends, to form a 750-yard termination for an overhead line in Canada, operating at 301 kV, 3-phase, with the centre point earthed. This is one of the highest voltages at which an industrial cable is at present operating anywhere in the world.

The cable, which is in course of manufacture at the Company's Eastleigh Works, will be of graded dielectric construction with lead sheath metal tape reinforced and served overall with an anti-corrosive finish (fig. 17). The carrying capacity of each cable is 530 amps. and the 3-phase circuit will carry 275 MVA. The cable has been designed by Pirelli-General and will be installed by their engineers. The joints and sealing ends are being supplied by Pirelli, Milan, who have collaborated in many of the technical problems involved.

MERCURY ARC RECTIFIERS.

The past year has been characterised by several important applications of the grid-controlled mercury arc rectifier to large power mechanical drives in which the output of the rectifier is controlled by automatic regulating systems including those associated with blowers for blast furnaces, rolling mills, boiler control, drawbenches, and printing presses.

At the Park Gate Iron and Steel Co., each of the 2,200 h.p. D.C. motors which drive the turbo-blowers referred to earlier in this article

are supplied by a 1,740 kW twin-cylinder grid-controlled rectifier. The first of these went into service at the end of 1951 and was followed by the second in the spring of 1952. A feature of interest is the cascaded arrangement of the phase shifters which vary the phase of the voltage impulses supplied to the rectifier grids which govern the outputs of the equipments. The blowers are started up under manual control through one phase shifter, but as soon as the blower delivers the required volume of air, the second phase shifter is brought into action automatically by the Askania controlled regulator which thereafter takes over the smooth and effective control of the blowers.

Another example of the use of grid-controlled rectifiers commissioned this year is the sheet skin pass mill at the Abbey Works of the Steel Company of Wales. For speeds up to 500 r.p.m. the motor driving this mill is controlled by the 330 kW, 0/440 volt equipment shown in fig. 18, a further increase in motor speed up to 1,000 r.p.m. being obtained by shunt field regulator control. This rectifier is also provided with field anodes for the excitation of the mill motor.

Automatic boiler control equipments which make full use of the grid-controlled rectifier are being installed in the new power stations of the British Electricity Authority at Huncoat and Uskmouth, the rectifiers being used to supply power to the driving motors of the forced-draught and induced-draught fans. The scheme at the Huncoat Station, which uses D.C. motors for all the boiler auxiliary drives, has been developed by the Company in close collaboration with Electroflo Meters Co. Ltd., and is covered by Patent Specification No. 662971. For each boiler there are two 255 kW, 0/500 volt grid-controlled rectifiers each of which supplies power to one forced-draught fan and one induced-draught fan motor so that these two fans are controlled as a pair. The output of the rectifiers is under the control of the automatic boiler control equipment which is governed by the boiler pressure and steam flow at any instant. The correct relationship between the speeds of the two fan motors is maintained by field regulator control of the induced-draught fan motor, the field regulator being actuated by an automatic control device which is dependent upon the pressure in the combustion chamber. A standard rectifier rated at 350 kW, 550 volts provides a constant voltage supply for all other boiler auxiliary drives and for the excitation of the fan motors.

The boiler house control at the Uskmouth Station, in which the electrical equipment operates in conjunction with automatic boiler house apparatus supplied by George Kent & Co. Ltd., differs somewhat from that at Huncoat. In this installation the boiler fans are driven by D.C. motors supplied from grid-controlled rectifiers with field anodes for the motor excitation. The two forced-draught fans are arranged to operate as one pair and the two induced-draught fans as another pair, their speeds being controlled automatically by the boiler control equipment which operates the phase shifters and so alters the voltage of the two rectifiers. These are rated at 576 kW and 242 kW for the forced-draught and induced-draught fan motors respectively. Other boiler house auxiliaries are driven by constant speed A.C. machines, the automatic control equipment serving to control their output by mechanical methods. Grid-controlled rectifiers rated at 884 kW, 750 volts are also used for the motors driving Gwynnes circulating water pumps whose speeds have to be adjusted according to the state of the tide and the load on the station, the total output of rectifiers for the whole station being 17,000 kW.

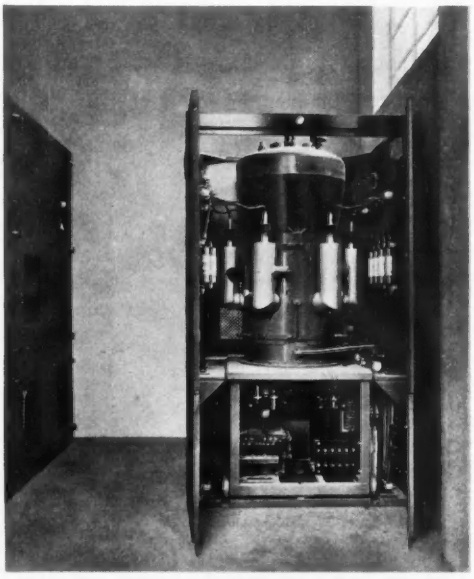


Fig. 18.—A 330 kW, 0/440 volt grid-controlled rectifier for controlling the 400 h.p. driving motor of the sheet skin pass mill at the Abbey Works of the Steel Company of Wales.

Grid-controlled rectifiers which operate in conjunction with electronic equipment for the

control of drawbenches have now been in service for the past twelve months and their performance has confirmed the suitability of these rectifiers for this service. Two multi-anode rectifiers of this type working in conjunction with electronic apparatus and rated at 100 kW, 440 volts, are now being built for printing press drives for the Kemsley Press.

Manually operated grid-controlled rectifiers are being made for Organic Products Ltd., at Klipfontein, South Africa. This chemical works has placed a repeat order for three 800 kW, 0/250/440 volt equipments, and when these are installed there will be 4,200 kW of G.E.C. rectifier plant in service at this Works. Also for use in the chemical industry, a further six 625 kW, 500 volt equipments have been supplied to Laporte Chemicals bringing the total number of units up to six.

For the steel industry, an 1,100 kW, 440 volt equipment has been ordered by Arthur Lee & Sons Ltd., for their Meadow Hall Works, Sheffield. The transformer will be rated at 3,300 kW so that the capacity of the rectifier can be increased at a future date. Ultimately, this will be the largest rectifier unit to be supplied by the Company. It is of interest to recall that it was at this steelworks that two 1,000 kW mobile rectifier substations (the property of British Railways) successfully maintained supplies for nearly twelve months while major repairs were effected to part of the power plant. These mobile units were originally supplied to the Southern Railway in 1942 and had not been used for nearly ten years. The fact that they could be brought into immediate service provides evidence of the excellent "shelf-life" of the steel tank pumpless rectifier. Other orders from steel works include a 200 kW, 500 volt equipment for the Whitehead Iron and Steel Co. Ltd., a 100 kW, 220 volt equipment for Ambrose Shardlow, and two rectifiers rated at 250 kW and 500 kW respectively for Tube Investments Ltd.

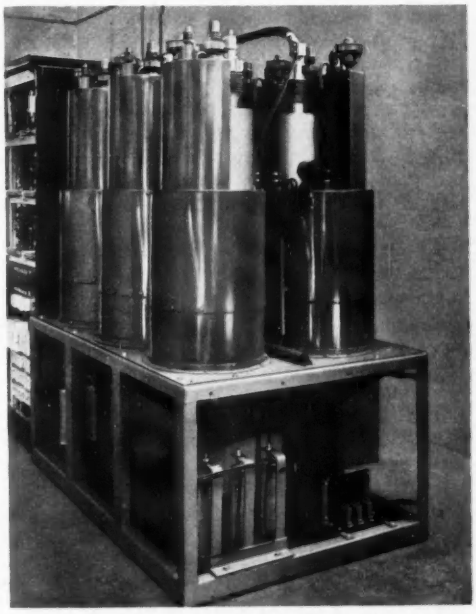


Fig. 19.—A six-cylinder 200 kW single anode rectifier equipment for a printing press drive.

Main line railway electrification equipment on order includes a 1,500 kW, 1,500 volt rectifier for the Victorian Railways, Melbourne, and a further order for two more 1,200 kW, 1,500 volt mobile substations for the Netherlands Railways. This latest order will bring the total of rectifiers for these railways to nearly 29,000 kW.

In addition to the overseas orders already mentioned, there are four 200 kW unit type substations for the Electricity Supply Board of the Republic of Ireland, two 400 kW equipments for Hong Kong, two 555 kW rectifiers for the Hague Tramways and two 3-wire equipments rated at 1,500 kW, 500/250 volts for Kanpur, India. A 60 kW unit is also being supplied to the Consolidated Gold Reef Mines in South Africa.

Last year's review of progress foreshadowed the introduction of the single anode pumpless steel tank rectifier for providing a D.C. supply from 3-phase A.C. mains without the introduction of any intervening transformer. Numbers of equipments of this type are being supplied for Witton-James Printing Press drives. Fig. 19 shows a six-cylinder unit rated at 220 kW, arranged for full wave rectification of a 3-phase, 400 volt supply.

(2) Mining Gear

COLLIERY WINDERS.

During the past twelve months, the four 4,200 h.p. geared A.C. winders for a new mine near Odendaalsrus in the Orange Free State have been commissioned. It will be recalled that these are the first winders to use the Company's new dynamic braking and motor control system described in an earlier issue.* For these winders the control operates on the principle of maintaining constant torque at all speeds for any given position of the driver's lever. This system of control has now been further developed to provide a rope speed which is directly related to the position of the operating lever while preserving the overriding torque limit feature. Hence the performance of the A.C. winder becomes similar to that of the Ward-Leonard controlled D.C. winder, the advantages of which have been established over many years.

The new system of speed control is also being applied to two new geared A.C. winders for the Afon and Cwm Collieries in South Wales. For the Afon Colliery, the winder motor is rated at 1,050 h.p., 3·3 kV, 490 r.p.m., while that for Cwm Colliery has an output of 3,000 h.p., 325 r.p.m. and drives a skip winder arranged for fully automatic working. A further point of interest is that this latter winder will be the first in the country to operate at 11 kV.

Two 3,700 h.p. geared D.C. winders are on order for the Silverwood East and Cadeby Main Collieries in the North Eastern Division of the Coal Board.

Each winder is designed to raise 528 tons of coal per hour from a depth of 2,299 ft. and is fitted with twin parallel drums 18 feet in diameter, which are driven through reduction gearing by an 0-320 r.p.m. D.C. motor. The 0-650 volts D.C. supply for this motor is provided by a 2,650 kW Ward-Leonard set driven at 500 r.p.m. by an 11 kV synchronous motor.

An interesting feature of the contract is the adoption of a scheme of cascade exciter control to ensure speed of response with high stability. In this instance the cascade exciters are used in conjunction with Ward-Leonard control and provide the excitation for the field of the generator which supplies the main winder motor.

Other orders in hand for the National Coal Board include sixteen electric haulages, ranging from 150 h.p. to 350 h.p. and it is of interest to record that extensive use is being made of the new system of speed control referred to above. Sixty-seven portable mining substations are also on order with outputs ranging from 75 kVA to 250 kVA for collieries throughout the country.

* "Principle and Features of a New Dynamic Braking and Motor Control System for A.C. Winders", by E. FRIEDLANDER, *G.E.C. Journal*, Vol. XVI No. 4, October, 1949.

CHROME ORE TREATMENT PLANT.

During the year the chrome ore treatment plant supplied to Sierra Leone Chrome Mines, Ltd., began operation. The mechanical portion was manufactured at the Erith Works, and the power plant and electrical equipment were supplied by the Witton Works.

The installation was planned in collaboration with the engineers of Sierra Leone Chrome Mines, Ltd., the preliminary mineral dressing tests being carried out at the Research Laboratories. The ore treated consists of chromite which occurs as small crystals disseminated throughout a siliceous matrix. The duty of the plant is to produce a concentrate having the minimum content of 42 per cent Cr_2O_3, 8 per cent, or less, of SiO_2, and a chromium to iron ratio of 2·8 to 1, or better. This specification is for metallurgical requirements. For use as refractories the Cr_2O_3 minimum is 40 per cent with 5 per cent SiO_2 or less.

The crushing section of the plant is designed to deal with 150 tons of ore in 8 hours, and the concentrating section with some 100 tons in 24 hours. The total installed motor power is 220 h.p., and the estimated day load, allowing a reserve of 25 per cent, is 260 kW. Water consumption is estimated at 360 gallons a minute, but, if necessary, much of this can be recovered.

Briefly, the treatment consists in crushing the ore to minus 2 in., trommel screening at $1\frac{1}{2}$ in., and picking out clean ore from the plus $1\frac{1}{2}$ in. size. The ore remaining after picking goes to a 2 ft. Symons cone crusher and is reduced to minus $\frac{3}{4}$ in. The minus $1\frac{1}{2}$ in. material from the trommel is conveyed to the Sherwen screen fitted with $\frac{3}{4}$ in. screen cloth. The oversize from this screen goes to the 2 ft. Symons cone crusher where it is reduced to minus $\frac{3}{4}$ in. with the plus $1\frac{1}{2}$ in. product. This minus $\frac{3}{4}$ in. ore is then conveyed to the fines bin which holds 200 tons of ore. From the bin the 30 in. travelling table feeder regulates the material at a constant rate to a system of Sherwen vibrating screens which delivers four fractions between the minus $\frac{3}{4}$ in. and plus $\frac{1}{16}$ in. to four sets of

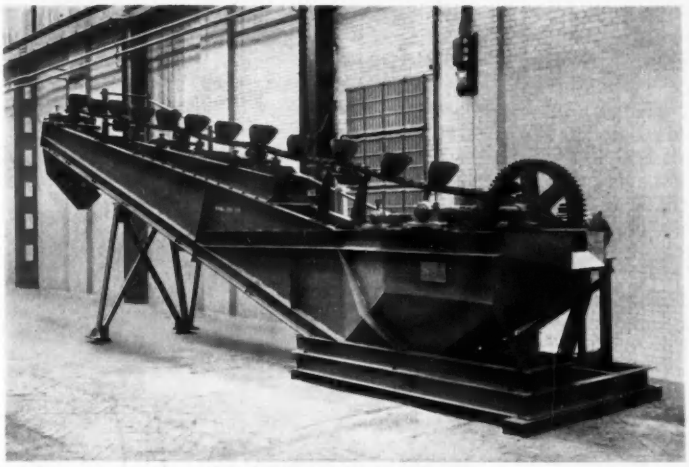


Fig. 20.—Dewatering conveyor.

two-compartment 24 in. by 12 in. Richards pulsator jigs. The middling products from the jigs and, if desired, the jig tailings, discharge into the dewatering conveyor seen in fig. 20, which delivers the solids to a 5 ft. dia. by 6 ft. long ball mill which is in closed circuit with the Rake classifier. The minus $\frac{1}{16}$ in. material from the screening system also goes to the classifier and ball mill. The overflow from the classifier passes by gravity to a three-way distributor and thence to three No. 7 concentrating tables.

The power station not only serves the mill but also provides the power for other installations of the undertaking. The plant comprises two 290 kW diesel-driven alternators together with switchgear, accessories and starting gear. Fourteen totally enclosed fan cooled motors, complete with control gear and the necessary drives, are employed for operating the mill machinery. The largest motor, which drives the ball mill, is a 70 h.p. slipring machine. The power plant and mill are housed in structural steel buildings.

HEAVY MEDIA SEPARATION PLANT FOR MANGANESE ORE.

A heavy media separation plant has been designed at the Erith Works for use in West Africa ; the flow sheet illustrating the cycle of opera-

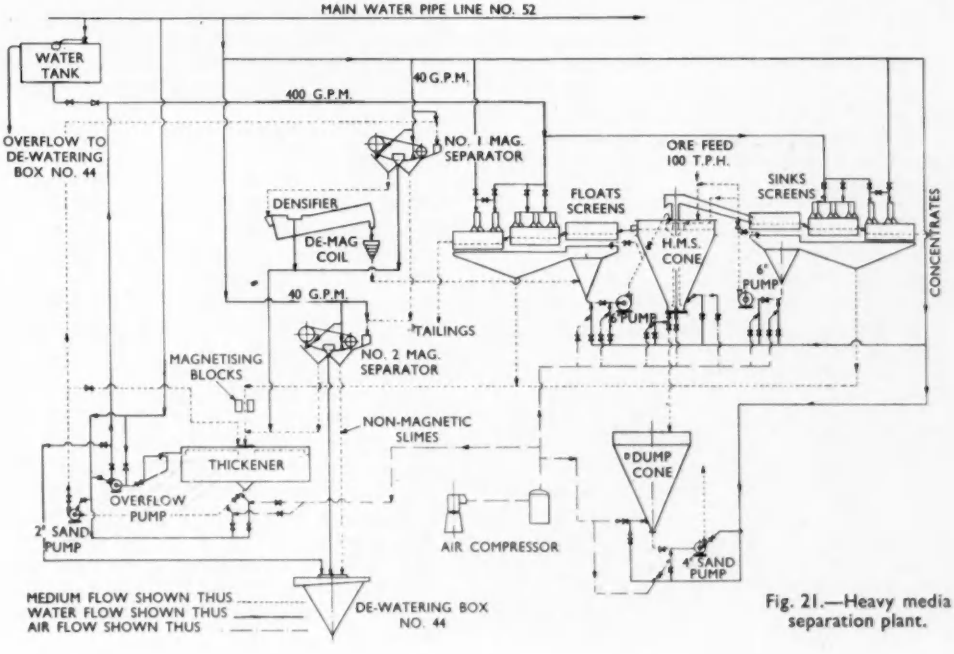


Fig. 21.—Heavy media separation plant.

tions is shown in fig. 21. The novel feature of this plant is that it will be used to treat 100 tons an hour of manganese ore of minus ¼ in. plus 28 mesh received from the log washer of an existing installation. The ore contains some 60 per cent of manganese ore and separation will take place at a specific gravity of 2·73.

The 14 ft. dia. separation cone is seen in fig. 22 in course of erection at the Erith Works. It is equipped with a 6¾ in. bore, internal air lift, to which are attached rake arms rotating at 5 r.p.m. driven by a 7½ h.p. reversible motor through a vertical fan-cooled worm reduction gear and a Vee rope drive. A further 14 ft. dia. cone is provided for dumping purposes.

The heavy media employed will be ferro-silicon containing some 15 per cent silicon and 85 per cent iron ground down to 98 per cent minus 65 mesh. Three special Sherwen screens, 5 ft. wide by 10 ft. long, are employed for draining the sink product which in this case is, of course, the valuable material. One of these screens is shown in fig. 23; three further 3 ft. wide by 10 ft. long screens of similar design being used for the float, or waste product. These screens operate horizontally and are fitted with ½ mm. wedge wire screen cloth.

In both cases the first of the three screens will be used to drain away the medium into hoppers from which it is pumped back to the cone ; the second and third screens are fitted with water sprays and the washings are sent to the media recovery section. Here the contaminated medium is passed through magnetising blocks to assist flocculation. It then passes to a 20 ft. dia. thickener from which the underflow is pumped back to two 48 in. wide wet magnetic separators of the Crockett type. The cleaned media is then passed to the densifier, after which it is demagnetised before return to the cone.

A large 48 in. Simplex double pitch densifier is employed for dewatering and storage of the clean heavy media. This is somewhat similar to the well-known Akins spiral classifier and is of heavy construction.

To avoid difficulty which might arise if the direct current needed for the magnetic separators should fail, a solenoid is fitted into the launder ahead of the separators so that the heavy media pulp is diverted back to the thickener in the event of such a failure and a red light operates.

CRUSHING AND SAMPLING AT THE ROYAL SCHOOL OF MINES.

Forty years ago the Erith Works provided the Royal School of Mines, South Kensington, with metallurgical and mineral dressing equipment for the then newly built Bessemer Laboratory. During the past year this laboratory has been considerably modernized and one complete room has been given over to the dry crushing of ores. The renovation of the machines and their re-installation in the Dry Crushing Room, together with the provision of new plant and ancillary structures, was recently undertaken

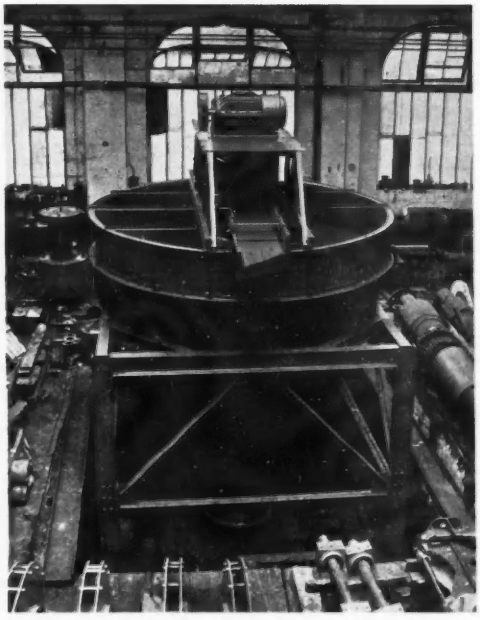


Fig. 22.—Separation cone in course of erection.

by the Erith Works in collaboration with the School Authorities and the consulting engineers.

The equipment comprises a weighing machine, 10 in. by 6 in. jaw crusher, 20 in. Symons cone crusher, 16 in. by 10 in. roll crusher, three-stage riffle, Sherwen screen, drying and sampling floor.

Ore is fed to the machines from a special hopper resting on a travelling carriage which is provided with a small magnetic feeder. This hopper is lifted by a 2-ton electric hoist, which travels on an overhead runway, from the floor level and fitted to the travelling carriage. The crushed and screened ore is collected from under the machines in similar hoppers mounted on special bogies.

In addition to the machines enumerated above, there is an installation of bench mounted small crushers and grinders for dealing with small samples.

The room as a whole has an air cleaning plant which serves the dual purpose of keeping the atmosphere in the Dry Crushing Room quite clean and allowing the dust made by each machine to be collected and weighed, thus ensuring that no part of a sample of ore is lost.

When the Dry Crushing Room is in full operation it will constitute one of the most modern and up-to-date plants of its kind.

KAPITALNA IRON WORKS, YUGOSLAVIA.

For the Kapitalna Iron Works, Zenica, Yugoslavia, a comprehensive contract has been received for a complete ore handling, crushing and screening plant which will handle 500/690 tons of ore per hour. The electrical equipment includes all cables and telephone equipment, and the completed installation will be generally similar to that at the Corby Works of Stewarts and Lloyds, Ltd., a full description of which appeared in this Journal, Vol. XVI, No. 3, July, 1949.

MINERAL DRESSING LABORATORY.

The Mineral Dressing Department at the Research Laboratories has been reorganised during the last two years, and the installation of new equipment and apparatus enables every recognised mineral dressing process to be applied. The low grade, difficult, or unusual ores at present being mined may call for a combination of several of these processes, and the Mineral Dressing Laboratory is well equipped to deal with this situation.

For treating ores in the coarser sizes a heavy medium separation plant has been installed. This is a complete unit of the smallest commercial size made by Fraser and Chalmers. It includes a wet magnetic separator for re-cleaning the ferro-silicon powder which, when suspended in water, constitutes the heavy medium in which a mineral separation can be made. For separating coarse material from fine before treatment by the heavy medium or other process, a 12 in. by 30 in. Sherwen vibrating screen, covering the 1 in. to 30 mesh range, has been obtained.

For treating ores in the finer sizes, in the 10 to 200 mesh range, a Humphreys spiral has been installed. This has the same function as the concentrating table, but its application is more limited because it will operate satisfactorily only when the specific gravity difference between wanted and unwanted minerals is greater than 1·0. It is a commercial size unit, and a plant incorporating over 1,000 of them is in successful operation in the United States. It has been found particularly valuable for concentration of ilmenite from beach sands.

The cyclone is coming into wider use as a means of making a size separation on a commercial scale right down to the 10 micron range, and a small unit is being made for testing ores amenable to this method of treatment. Normally, size separations in the range below 30 mesh are made with a hydraulic classifier designed at the Research Laboratories; the important feature of this is a Rotameter for the measurement and control of the water creating the rising current by which the separation is made. The difficulty of maintaining a steady uniform feed of finely ground wet material to the classifier and other machines has been overcome by means of a small H2 Mono pump. This operates in closed circuit with a specially designed tank, the feed being drawn off from the delivery side of the circuit.

A most useful laboratory tool for the control of test work is the Superpanner, a device developed by Professor Haultain for studying the Canadian gold ores. Using a small sample of finely ground ore, it makes a very accurate

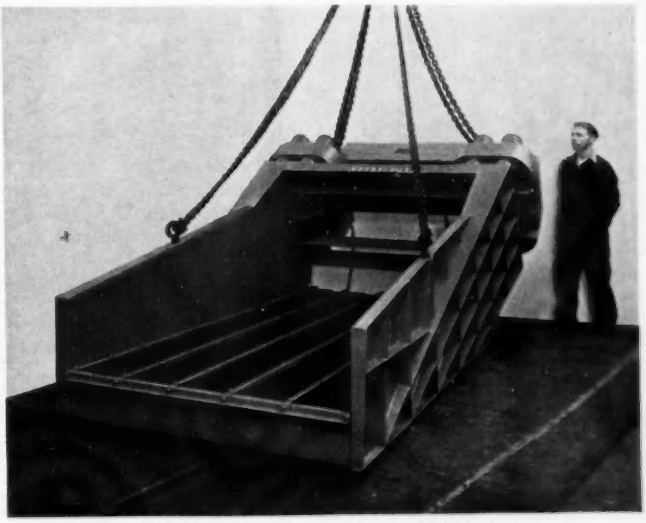


Fig. 23.—Sherwen screen, 5 ft. wide by 10 ft. long.

separation of minerals which are only very slightly different in specific gravity. In conjunction with X-ray diffraction it is valuable for determining the identity of very small quantities of unknown mineral.

SIGNALLING AND MOTOR CONTROL EQUIPMENT FOR COAL FACE CUTTERS.

This system employs a wire extending the length of the coal face alongside the conveyor. The wire is usually suspended above the conveyor and is anchored at one end to a hand-winch clamped to a prop. At the delivery end of the conveyor the wire is attached by a turnbuckle to a pull switch on the control box (fig. 24).

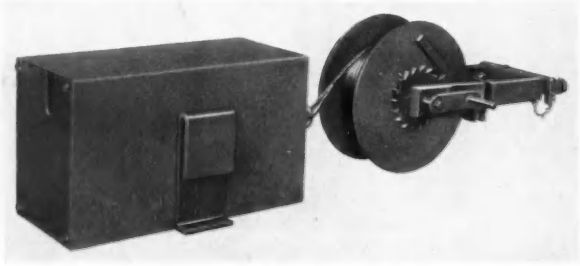


Fig. 24.—Control box and winch for signalling and control of coal face conveyor.

The pull switch has two sets of contacts : one operating the signal bell or hooter, the other in direct connection with the gate-end box where it opens the contacts of the pilot circuit thus immediately stopping the conveyor motor. The pull switch is mounted inside a sheet steel container which also accommodates a bell and battery, fig. 25. Brackets are provided on opposite sides of the container, enabling two units to be mounted end to end as would be required on faces where double conveyors are used. The bell is operated by an approved type of dry battery, and as the bell is of an intrinsically safe type the whole circuit is intrinsically safe.

A slight pull on the wire will operate the switch at distances up to 400 yards from the delivery end of conveyor. This system has been tested for a considerable time in both thick and thin seams and has given complete satisfaction. It should be noted that the equipment can be used not only to stop the conveyor in an emergency, but also to convey signals by the use of a suitable code. In such cases the conveyor is stopped only for a moment and production is not appreciably interrupted.

SHAFT SIGNALLING—DOUBLE DECKING.

Where simultaneous loading of two-deck cages is practised the local signalling between the onsetter, banksman and their assistants has, in the past, been of a very crude type which can easily be mistaken. Furthermore, if no visual signal is provided, as has frequently been the case, the onsetter or banksman has to rely on his memory as to whether the signal has, or has not, been given. When men are being lowered this may involve serious risk. Consequently the G.E.C. has devised an electric system of signalling which can be utilised in conjunction with the dial shaft signals. The equipment comprises an indicator and bell or hooter fixed on the onsetter's or banksman's landing with push buttons on the assistant's landing.

When the assistant onsetter is ready on his deck he presses the start button which rings the audible signal and switches on the green light. This light remains on until the onsetter gives his action signal to the surface thereby automatically cancelling the green light. If, for any reason, the assistant wishes to stop the action after having given the " go " signal, he presses the stop button which cancels the green light, rings the bell and operates the red light which he alone is able to cancel when the danger is cleared. Both the red and green lights have lamps in duplicate to avoid the danger consequent upon a lamp burning out. A duplicate system is fitted at the pit bank.

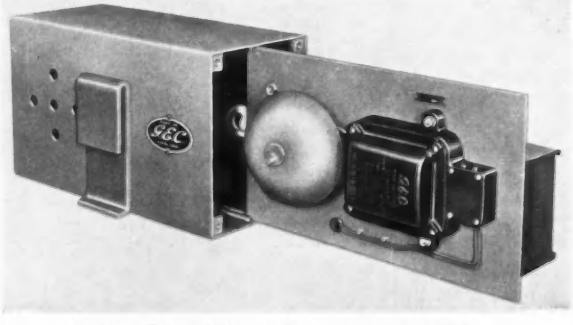


Fig. 25.—Control box with chassis partly withdrawn.

(3) Materials Handling

Fraser and Chalmers Engineering Works have supplied to the order of Simon-Carves, Ltd. for John Summers Steel Works a complete coal blending and handling plant. The equipment comprises two wing trippers, two Messiter reclaimers, each capable of discharging 460 tons an hour on to the coke oven conveyors, and one transfer car to move the reclaimers from the end of one pile to another within the coal stocking yard.

Fig. 26.—The self-unloading bauxite ore carrier "Carl Schmedeman".

Reference has already been made to the equipment to be supplied to the Kapitalna Iron Works, Zenica, Yugoslavia. The value of this order, which was placed by Invest-Import of Belgrade, is in excess of £1,000,000. In addition to the crushing and screening plant mentioned, conveyors have been supplied to the number of 68 which includes some 20,000 feet of belt. Ore is received at the plant to a maximum size of 24 in. and is reduced to 2½ in. for furnace feeding. 2,300 h.p. is required to drive the equipment at its maximum capacity when handling ore at 690 tons per hour. Crushing equipment is provided to reduce smalls to 3 mm. at which size it is fed to the sintering plant.

Equipment has been supplied for a self-unloading bauxite ore carrier, the "Carl Schmedeman", built by Vickers-Armstrongs, Barrow, and owned by Reynolds Jamaica Mines, Ltd. (fig. 26). The handling plant consists of two hold conveyors, port and starboard, each 397 ft. long, handling the gravity discharge from inbuilt hoppers and each having a capacity of 700 tons an hour. The two hold conveyors have a rise of 38 ft. and discharge on to a shuttle conveyor mounted athwartships which discharges through specially constructed doors at either side of the ship at will.

The shuttle conveyor is extensible from within the ship's sides by 11 ft. 3 in. This extension to the conveyor is carried out pneumatically. Two 100 h.p. motors and one reversible 20 h.p. motor provide the required drives through flexible couplings for the belts and two 10 in. Witton-Kramer solenoid brakes are fitted to the hold conveyors.

In the South Eastern Division of the British Electricity Authority, extensions to the coal-handling plant are in hand at the Littlebrook Power Station, near Dartford, Kent. The original plant was installed by Fraser and Chalmers and the new equipment will serve the augmented generating equipment now being built. The contract comprises an additional conveyor on a jetty extension for off-loading vessels, together with another conveyor supplementing the existing coal stocking and boiler house feeding facilities. The pile stocking provisions are extended beyond their present limits by the construction of a storing conveyor and reclaiming conveyor, to be run to the new stocking area. The existing arrangements allow the coal required by the "A" and "B" Power Houses to be reclaimed by travelling bridge grabs. The new conveyors will feed coal to the stocking piles by a radial conveyor and will reclaim this coal by "bulldozing" on to the reclaiming conveyor for feeding into the new "C" Power Station, and existing "A" & "B" Stations. This additional equipment not only extends the coal handling facilities, but, in conjunction with the present equipment, transfers coal from any one stock pile area to any one of the three separate generating stations.

(4) Rolling Mills

The two 2-stand temper mills at the Trostre Tinplate Works of the Steel Company of Wales have now been commissioned, one of the mills being shown in fig. 27. Each stand is driven by a 1,000 h.p. motor, which together with the driving motors of the tension rolls are supplied from a 2,000 kW motor generator set. A second motor generator supplies power for the 300 h.p. uncoiler and reeler motors. The speed of the mill as a whole is varied by controlling the voltage of the generators of the motor generator-sets, the equipment being so designed that the time taken to accelerate the mill from rest to the full speed of 4,000 ft. per min. can be varied from 12 to 20 seconds, while that for stopping the mill from full speed can be adjusted between the limits of 5 to 20 seconds. In order to preserve the correct tension in the strip, extensive use is made of cascade exciters, which are used for regulating the output of both the main and auxiliary motor-generators and for each of the motors driving the stands, tension rolls, uncoiler and reeler. As the speeds of the stand motor and the uncoiler and reeler motors demand particularly accurate control, the cascade exciters for these drives operate in conjunction with electronic amplifiers. The performance of the mills has indisputably demonstrated the suitability of the cascade exciter system of control for rolling mill drives.

At the Abbey Works of this steelworks the coil skin pass mill and sheet skin pass mill (fig. 28) are now in operation. The former is driven by a 700 h.p. 500/1,000 r.p.m. motor, and the latter by a 400 h.p. 0/500/1,000 r.p.m. motor supplied from a 330 kW grid-controlled rectifier. The contactor control panel for this mill is seen in fig. 29 and further reference to the system of speed control by grid controlled rectifiers is made in the section dealing with mercury arc rectifiers.

The two strip mills at the Kynoch Works of Imperial Chemical Industries are now in opera-

Fig. 27.—No. 1, two-stand temper mill at the Trostre Tinplate Works of the Steel Company of Wales, showing the 1,000 h.p. mill motors and the 500 h.p. tension roll motors.

tion. For this installation all the electrical equipment was supplied by the Company, and includes the two 500 h.p. 250/625 r.p.m. main driving motors, which are supplied from a 1,000 h.p. motor generator set, and a further eighteen A.C. motors with their associated control gear for operating the mill auxiliaries.

Contracts received include one from the Loewy Engineering Co. Ltd., for the complete electrical equipment for a brass rolling mill for the Ministry of Supply. The main mill motor is rated at 1,000 h.p. 0/145/225 r.p.m. and, together with the 240 h.p. edger motor, is supplied from a 1,100 h.p. motor generator set. For the Australian Iron and Steel Company, Port Kembla, New South Wales, equipment is on order for hot finishing mill auxiliaries including coiler, run-out table and loop lifter drives. This contract includes two 7-machine motor generator sets, each driven by a 1,550 h.p., 3·3 kV, 1,000 r.p.m. synchronous motor arranged for reactor starting; two 300 h.p. 0/300/900 r.p.m. motors for the mandrel drives and all the associated contactor switchgear and control desks.

Fig. 29.—Contactor panel for the sheet skin pass mill in the Abbey Works.

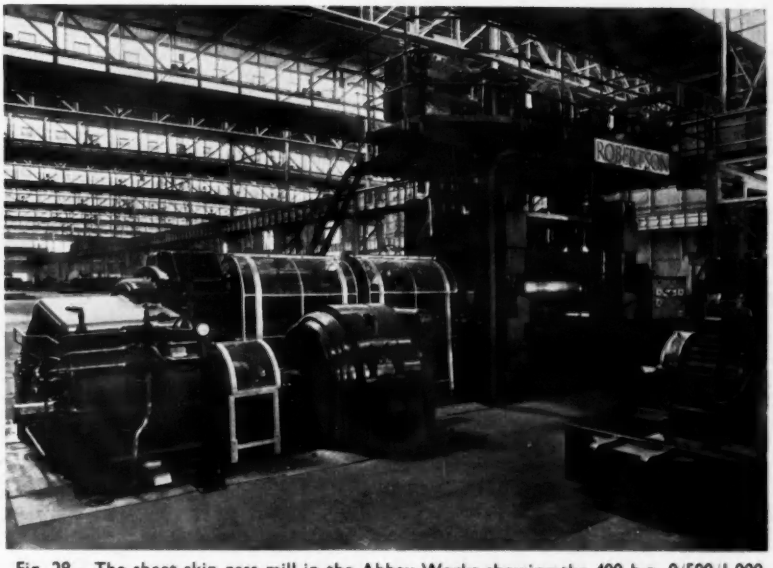


Fig. 28.—The sheet skin pass mill in the Abbey Works showing the 400 h.p. 0/500/1,000 r.p.m. mill motor in the foreground.

(5) Industrial Electrification

OIL INDUSTRY.

Large numbers of motors for driving oil well pumps for the Shell Petroleum Co. Ltd., are now in service, and many more are in course of construction, a typical installation being shown in fig. 30. These machines are of the squirrel-cage high torque type and are built to withstand all weather conditions as they have to operate in the open and may remain unattended for weeks on end.

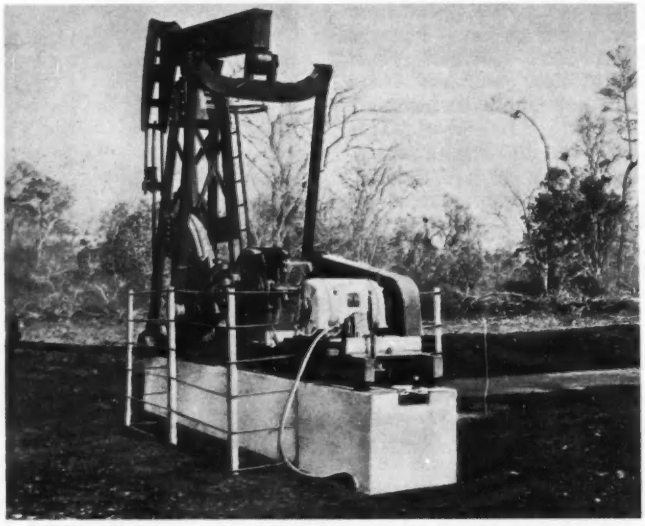


Fig. 30.—A high torque squirrel cage motor driving a beam type well pump on one of the oil fields of Shell Petroleum Company in Venezuela.

CEMENT WORKS.

Much of the electrical plant for the new Shimshon Portland Cement Works in Palestine is now in course of erection. The whole of the electrical equipment has been supplied by the G.E.C. and includes diesel-electric generating plant totalling some 8,000 kW, four 1,000 kVA, two 600 kVA and three 250 kVA transformers, switchgear and over 9,000 h.p. of slipring and squirrel-cage motors. For the Associated Cement Co. Ltd., in Bombay, there are on order twenty-four totally enclosed fan-cooled slipring machines with an aggregate output of over 1,560 h.p.

ELECTRO-MAGNETS.

Throughout the year orders for lifting and separator magnets (fig. 31) ranging from 26 in. to 64 in. dia. have increased and equipments are being built for service in this country and for export to Canada, Northern Rhodesia, U.S.A. and Sweden. They include special water-cooled magnets for charging billets into rotary hearth furnaces. One of these magnets, operating in conjunction with a charger made by the Salem Engineering Co. Ltd., has recently been commissioned at the works of Tubes, Ltd. For this duty, the lifting magnet offers two important advantages. First, the billets can be charged, either with their ends touching or with very little gap between them and, second, as more than one billet can be picked up at a time, the furnace has to be charged less frequently thus reducing heat losses.

As the lifting magnet has to be inserted into the furnace, its design and construction must be such that it will withstand temperatures of the order of 1,100 degs. C. without detriment. Satisfactory performance of the magnet at these

high temperatures has been achieved by providing water jackets along each side of the magnet and extension arm of the charging machine, independent water circulation being provided for each cooler.

BRIDGE ELECTRIFICATION.

For the modernisation of the operating equipment of a double bascule bridge spanning Walney Creek at Barrow, an order has been placed on behalf of Barrow Corporation by W. H. Smith & Co., Ltd., for all the electrical plant and control gear. Each leaf of the bridge is operated by a 25 h.p. motor arranged for Ward-Leonard control and duplicate driving motors are installed as standby units. The sequence of interlocking, warning bells, navigation signals, and for raising and lowering the bridge is fully automatic and under the control of a single hand-wheel.

Another interesting contract for electrical equipment is that placed by the Cleveland Bridge and Engineering Co. for a single bascule bridge which is to be erected at The Spit, Middle Harbour, Sydney, New South Wales. In this instance the main driving motor is of the A.C. slipring type rated at 125 h.p. and the contract includes a 10 kVA, engine-driven stand-by alternator, nine auxiliary gate motors, road traffic signals, navigation and bridge lights and a public address system. Provision is made for fully automatic working, a comprehensive system of interlocks preventing any risk of mal-operation. The bridge is operated from a control panel on which a mimic diagram shows the position of the bridge and gates.

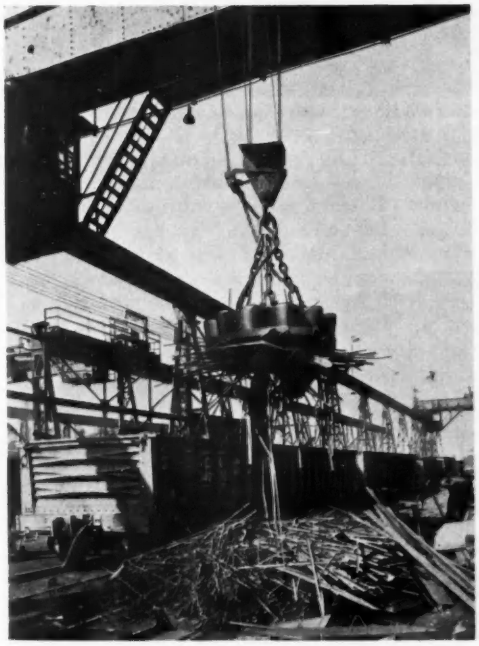


Fig. 31.—A 64 in. lifting magnet loading scrap metal in a Canadian steelworks.

TEXTILE ELECTRIFICATION.

Of the contracts now in hand for the textile industry particular interest attaches to that recently sponsored by the Government of Pakistan. This is a project for increasing production at the Fauji Textile Mill at Kala in the Punjab. The mill is operated by the Board of Post-War Services Reconstruction Fund, and has a present capacity of 25,184 spindles. When the extensions now in progress are completed the output of the mill will be doubled. In all, the Company is supplying 218 squirrel-cage motors with direct-to-line starters. Of this total 122 machines are of the standard industrial pattern with outputs ranging from $\frac{1}{2}$ h.p. to 12 h.p., while the remainder are specially constructed for carding engine drives and are rated at $1\frac{1}{2}$ h.p.

Further extensions to the Pakistan textile industry are taking place in the East Punjab where several new jute mills are being erected for the Pakistan Industrial Development Corporation. Orders have so far been received for ninety-eight slipring and squirrel-cage motors totalling nearly 3,000 h.p. for these mills.

EQUIPMENT FOR THE CANADIAN MARKET.

During the period under review Canadian Standards Association (C.S.A.) approval has been obtained for an extensive range of equipment including induction motors up to 600 h.p., direct current motors and steelworks motors up to 200 h.p.; a range of A.C. and D.C. contactors.

Approval has also been obtained for Witton Kramer magnetic brakes, A.C. and D.C. solenoids and D.C. lifting magnets from 26 in. to 64 in. dia.

Progress has been made in the development of a range of A.C. squirrel cage motors to N.E.M.A. dimensions and several consignments have been shipped to Canada.

(6) Transport

TRACTION.

Delivery is in progress of the forty 3,000 volt, 3,030 h.p. main line locomotives for the South African Railways and Harbour Administration, the mechanical portions of which were built by the North British Locomotive Company, and some are now running between Durban and Volksrust on the Natal main line. Later they will operate between Cape Town and Beaufort West when the electrification of that line is completed.

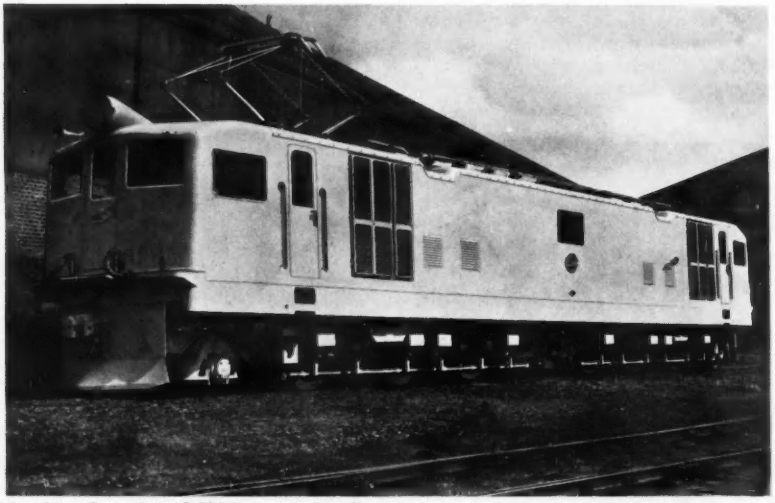


Fig. 32.—One of the 3,030 h.p. main line locomotives now in service in South Africa.

Service tests which have included hauling and starting freight trains of 1,200 short tons on a 1 in 66 gradient have been very satisfactory, while at speeds of 60 m.p.h. the riding characteristics have been particularly good.

These locomotives (fig. 32), which are believed to be the most powerful in the world to operate on a 3 ft. 6 in. gauge, each have a total weight of 155 tons, the load on the driving axles being 129 tons and the length over the couplers being 72 ft. 2 ins. They are designed to haul passenger and goods trains at speeds up to 60 m.p.h., regenerative braking being provided to control the speeds down long gradients. The locomotives are of the double bogie type, each bogie having three driving axles and a leading guiding axle. They are powered by six motors, arranged as shown in fig. 34, with a total one-hour rating of 3,030 h.p. at full field and 3,150 h.p. on weak field. The locomotives are supplied from a 3,000 volt D.C. overhead line and the motors are arranged to operate in three combinations when either motoring or braking, the

Fig. 33.—One of the 505 h.p. type WT. 580 traction motors.

final combination comprising three groups of two motors in series across the line.

One of the 505 h.p. driving motors is shown in fig. 33. These machines incorporate some interesting design features which include the use of high melting point solder for all commutator joints and a patented interpole magnetic circuit whereby the optimum interpole strength is preserved over the widest possible range of load. In order to meet the severe service conditions which involve prolonged operation over steep grades and sharp curves, their mechanical construction is extremely robust, particularly in so far as the suspension bearings are concerned.

When regenerative braking is being used, the motor fields are energised by a 43 kW exciter set driven by a 2-pole 3,000 volt motor, which also drives a blower for supplying the cooling air for three of the traction motors. As the exciter characteristics must be kept within close limits, the generator is provided with dual grade split brushes so that the characteristics of the set are not unduly affected by the long periods of no-load running encountered in service. A similar set, rated at 22 kW, supplies the L.T. power on the locomotive and the cooling air for the other three traction motors.

The main items of control equipment have already been described in a previous progress review,* so that it is only intended here to refer to the arrangement of the apparatus on the locomotive. The driver's cab is shown in fig. 35 from which it will be noted that the driver sits towards the offside of the locomotive, with the master controller on his left side and the straight air and vacuum brake valves on his right. Immediately in front of the driver is the instrument and indicator panel. At the top of this panel are the straight air and duplex brake gauges, below which are the excitation ammeter, line voltmeter, main motor voltmeter and main circuit zero reading ammeter (not visible in the illustration). These instruments serve as a complete guide to the operation of the locomotive both when motoring and when employing regenerative braking. As, under certain conditions, these instruments might become alive at 3,000 volts, they are completely insulated from earth and from each other, and are protected by a splinter-proof glass cover. Illumination is by indirect diffused lighting, so arranged that no type of fault can result in connection between the 3,000 volt and L.T. lighting circuits.

The upper part of a group of main electro-pneumatic 3,000 volt contactors with the over-load, over-voltage and no current relays mounted above, is seen in fig. 36.

During the period under review, the repeat order for nine motor coaches, four driving trailers and one trailer coach for the Sociedade Estoril, Portugal, has been completed and the new equipment is now in service. It will be recalled that a full description of the traction equipment previously supplied formed the subject of an article in an earlier issue of this Journal.*

Motors and control gear for a further 24 trolley buses for Belfast Corporation Transport

* "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIX, No. 1, January, 1952.

* "Railway Equipment for Sociedade Estoril, Portugal," by E. H. CROFT. *G.E.C. Journal*, Vol. XVIII, No. 2, April, 1951.

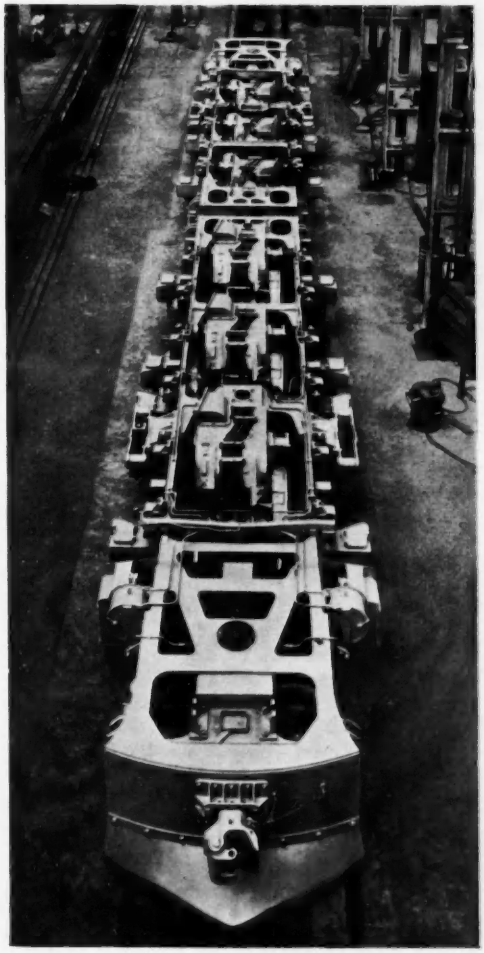


Fig. 34.—General view of the two bogies showing the disposition of the six 505 h.p. driving motors.

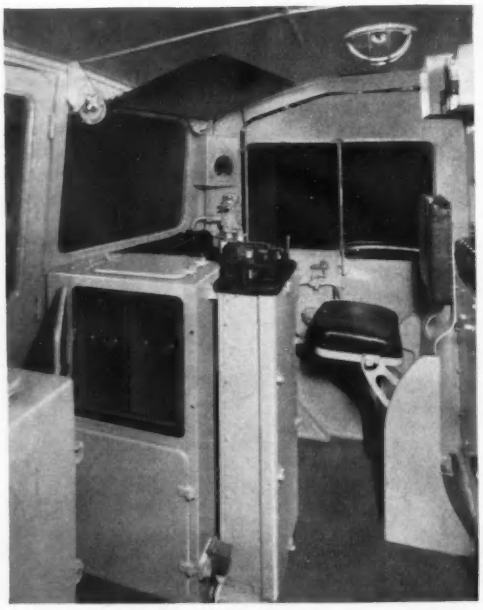


Fig. 35.—Driver's cab showing the layout of the equipment.

Department have been despatched to the chassis builders. These new buses will bring the total number equipped by the Company up to 207. A full description of this trolley-bus system has already appeared in this Journal,* and one of these double deck buses is seen in fig. 37.

For the new buses the controller is of the butt contact type embodying automatic acceleration by means of a current-controlled oil dashpot. As the master controller is connected by a spring drive to the pedal, it will only follow pedal movement if free to do so. The oil dashpot has two valves, the main valve being controlled by the relay carrying the motor current. So long as this current is below a predetermined value, the relay will drop and open the main valve, allowing the master controller to follow the pedal. Any rise in current will close the valve and immediately arrest progressive movement of the controller. A second valve serves to avoid any risk of stalling by permitting the controller to follow the movement of the pedal at a slow rate, regardless of the current control of the main valve.

* "Trolley Bus Equipment for Belfast Transport Department," by Col. R. McCreary, O.B.E., M.C., B.Sc., M.I.C.E., M.Inst.T. and E. H. Croft, A.M.I.C.E., M.I.E.E., *G.E.C. Journal*, Vol. XVI, No. 3, July, 1949.

MARINE ELECTRICAL EQUIPMENT.

In the progress review which appeared in the January 1952 issue of this Journal, attention was directed to the increasingly wide adoption of alternating current for engine room auxiliaries. During the past twelve months this trend has continued and the Company has been entrusted with a large proportion of the orders placed for such machinery. From one shipowner alone, contracts have been received for twelve complete equipments, each comprising two 550 kW, 440 volt, 60 cycle, turbo alternators, a 200 kW diesel-driven set, main A.C. cubicle type switchboard, two group starter boards and some 45 squirrel cage motors ranging from 1 h.p. to 178 h.p. Many equipments of a similar nature are in hand for shipowners both in this country and overseas.

Although most of the A.C. installations at present under construction are for tankers or bulk cargo carriers, the Company has in progress a contract for alternators and motors for a North Atlantic liner, which will be the first passenger vessel built in this country with A.C. throughout the ship.

The general activity in the shipyards has also been reflected in the number of conventional

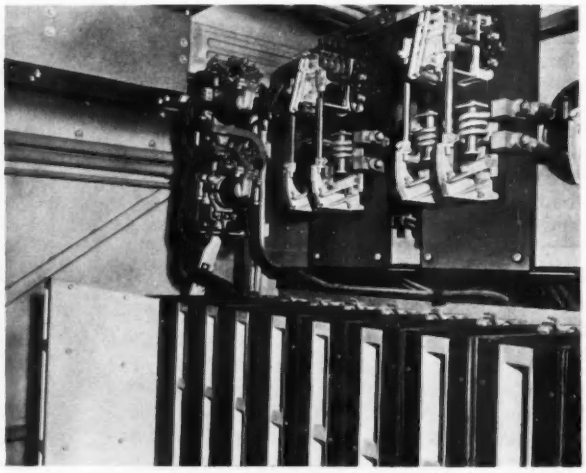


Fig. 36.—Protective relays mounted above the 3,000 volt contactors.

Fig. 37 (*left*).—Double deck trolley bus for Belfast Corporation.

direct current equipments on order. Twelve ships for one owner are being thus equipped, the gear to be supplied for each vessel comprising two 325 kW geared turbo generators and auxiliary motors ranging from 10 h.p. to 90 h.p.

A steady demand for plural starting equipment continues, and recent contracts include a further five boards for the P. & O. Steam Navigation Co. Ltd., another for the "Santa Maria", a sister ship of the "Vera Cruz" in which similar equipment is in service. It is of interest to recall that the plural starter board in the "Vera Cruz" controls forty motors, with outputs up to 258 h.p., and is the largest ever supplied by the Company. Electrical engine room and refrigerating equipment in the motor vessel "Wellington Star" is now in service. It includes four 330 kW D.C. generators, main and auxiliary switchboards, some 78 motors ranging from 1 h.p. to 160 h.p., and a plural starter board.

Fig. 38.—Cold cathode lighting in the tourist Lounge of the "Vera Cruz".

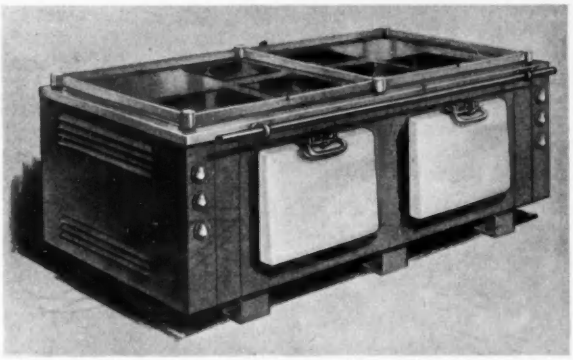


Fig. 39.—New two-oven galley range for use in medium size vessels.

This is the last of eleven ships built since the war for the Blue Star Line all of which have been similarly equipped by the Company. It is to be noted that in the course of this building programme the Blue Star Line has incorporated the refrigeration compressors (160 h.p.) in the plural starting system, which has resulted in a substantial saving of space in the refrigeration machinery room.

The cold cathode lighting in the "Vera Cruz" mentioned in this Journal in January 1952, is now in

service and has proved a most pleasing and successful installation (fig. 38).

Numerous important and interesting lighting contracts are in progress including combined tungsten and hot cathode schemes for the " City of Port Elizabeth " and " City of Exeter ", which are building for the City Line, and a combined cold cathode, hot cathode and tungsten scheme for the 28,000-ton passenger liner now building in the yards of John Brown & Co. Ltd., for the P. & O. Steam Navigation Co. Ltd. A 600-line manual and 200-line automatic telephone installation are being supplied to this ship as well as to the sister ship building at Belfast. The popularity of telephones as a means of shipboard communication steadily increases and orders are in hand for widely varying systems to meet specific requirements.

The G.E.C. luminous call system continues to find favour, among the many installations in hand being those for the " Santa Maria " and the two 28,000-ton P. & O. liners mentioned above; in these ships the luminous call system is found to be an admirable complement to the telephones.

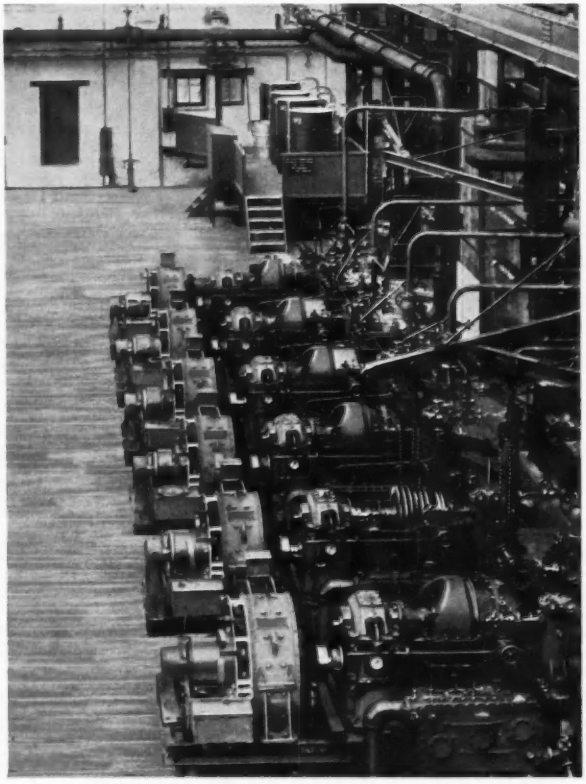


Fig. 40.—Six sets of 400 kW, 225/230 volt, D.C. generators, for marine use, in course of erection.

A substantial amount of galley equipment is in hand, and here again the Company has pioneered equipment for use on 440 volt, 3-phase A.C. supplies. Other new features are thermostatic oven control and Simmerswitch control of the hotplates which are incorporated for the first time in apparatus for marine service. To meet the persistent demand for a galley range suitable for the intermediate vessels catering for a complement of 35/45 people a new two-oven range of moderate dimentions has been developed which is most attractive in appearance, neatly constructed and incorporates several new features including self-supporting drop-down oven doors (fig. 39).

The trend towards A.C. is leading naturally to a demand for " Mutac " switches in the quarters occupied by passengers and crew. The fact that " Mutac " switches, with their silent action, can be used in these ships where A.C. is installed will overcome one of the greatest annoyances of the past arising from the irritating noise of quick make-and-break D.C. switches mounted on cabin panelling.

(7) Electronic Control

ELECTRONIC CONTROL APPLICATIONS.

Among important developments in the art of electronic control are the special amplifiers (fig. 41) for use in connection with the electronic control of D.C. printing press drives which operate in conjunction with single or multi-anode rectifiers. Accurate control of the press is obtained over the whole speed range of the driving motors, while inching and threading can be effected when using the main drive, thus obviating the need for additional auxiliary equipment. Also for the printing industry there is an electronic device for accurately controlling the peripheral speed of the reels of automatic pasters, so that the speed of the incoming newsprint is closely matched with that of the paper running through the press to enable a join to be made.

A good example of the accuracy of control afforded by electronic equipment, is provided by the installation at the works of L. B. Holliday & Co. Ltd., where this form of control is used to give high precision constant current regulation of a 360 kW grid-controlled rectifier for electrolytic duty.

In an earlier issue of this Journal* a full description was given of the application of electronics to the control of a large planing machine, the driving motor of which was supplied from a grid-controlled rectifier. Electronic control has now been extended to Ward-Leonard drives, and equipments are being produced for a Swift-Summerskill planer and a Craven Brothers slotter, using this form of drive.

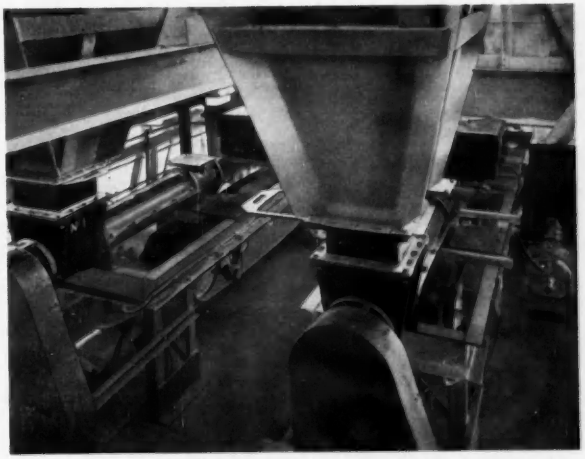


Fig. 42.—Two screw-feeder type Simon patent constant weight feeders in one of the Works of Imperial Chemical Industries, Ltd.

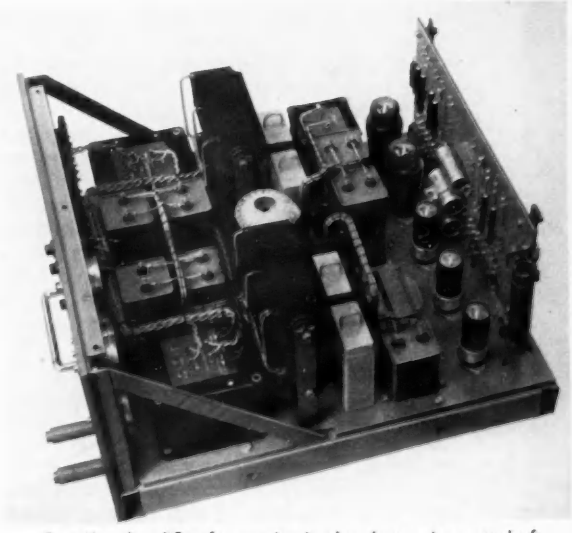


Fig. 41.—Amplifier for service in the electronic control of printing press drives.

A somewhat unusual example of the application of electronic control is the continuous regulation of material flow. Automatic weighing equipments of this type (fig. 42) have been in service for some time at one of the works of Imperial Chemical Industries Ltd. Each provides a regulated flow of approximately 10 tons of powdered

* "The Servo Electronic Control of a Large Planer," by S. H. DALE, *G.E.C. Journal*, Vol. XVI, No. 1, January, 1949.

limestone per hour. The rate of flow is maintained automatically at the desired value to within plus or minus 4 per cent by the electronic apparatus which operates in conjunction with a continuous weighing device and determines the speeds of the motors driving the screw feeder and conveyor belts. A view of the electronic control cubicles is seen in fig. 43.

PHOTO-ELECTRIC DEVICES.

In the progress review published in this Journal in January 1952, a description was given of a patented photo-electric press-guard, in which a modulated light beam, which was reflected back and forth, provided a positive safeguard for the operator. In a further development of this scheme, multiple horizontal light beams are used, the distance between adjacent beams being such that sheet metal can be inserted in the press without interrupting the light rays, but if the operator's hand follows the sheet the beam of light is broken and the press immediately halted. In all other respects, this new photo-electric press-guard is similar to the original design. A 12 ft. wide brake press, on which the new equipment is fitted, is shown in fig. 44.

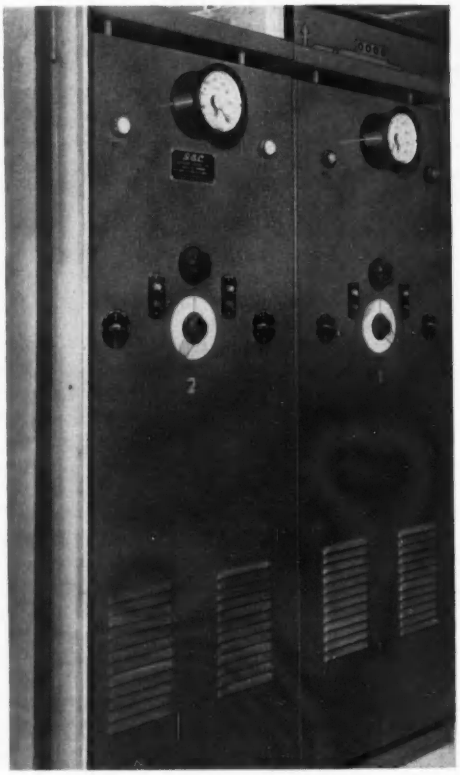


Fig. 43.—Electronic control cubicles for the constant weight feeders shown in fig. 42.

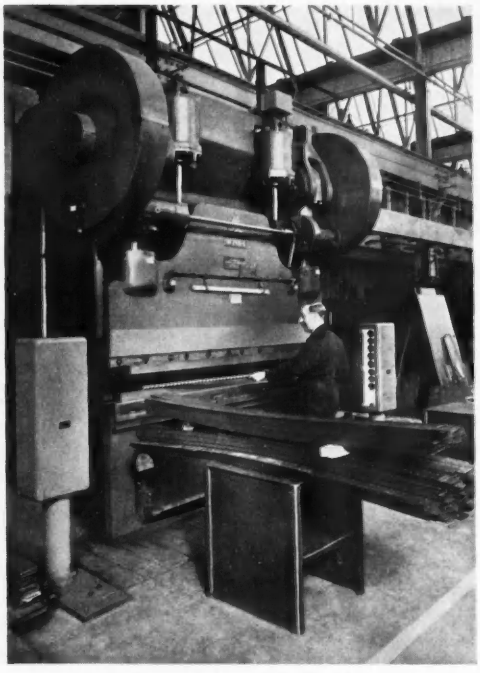


Fig. 44.—Photo-electric press guard fitted to a large brake press.

Another interesting application of the photo-cell is to be found in the control of the flying crop shear of the 80 in. continuous hot strip mill at the Abbey Works of the Steel Company of Wales. The operation of the shear is initiated by light radiated from the hot metal striking a photo-electric cell. Owing to the close proximity of the unit to the hot metal, it is subjected to unusually high ambient temperatures, and is therefore arranged for water-cooling. The equipment comprises two parts, namely, the photo-electric head and the power supply unit. The former houses the light-sensitive photo-cell with its associated amplifying valve. It is constructed so that the complete chassis on which the equipment is mounted can be withdrawn easily without interfering with the alignment of the unit or interrupting the water supply. Dust and dirt are excluded by a heat-proof protective

glass fitted at the front, while provision is made for fitting a tubular extension to limit the field of view.

The power supply unit, which comprises the mains-transformer relay and capacitors, is built into a strong aluminium box and operates from the main 400 volt supply. It is connected to the photo-electric head by multi-cored cable which may be of any length up to 100 yards so that it is necessary to design this part of the equipment for service only in normal ambient temperatures.

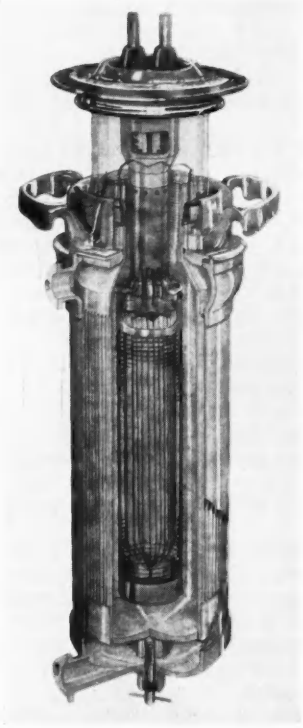


Fig. 45.—New high-powered water-cooled anode triode valve for the Harwell cyclotron.

POWER SUPPLY FOR CYCLOTRON.

A new high power water-cooled anode triode valve has been developed for use in the Harwell cyclotron. It is required to handle an input of 20 amp. at 15 kV under oscillatory conditions at a frequency not less than 25 Mc/s. An efficiency no lower than 50 per cent was required so that 300 kW of radio frequency power would be available from two valves operating in parallel.

It was known that the CAT.17, which has been used for many years in high power short-wave broadcast transmitters, would handle the power adequately, but its efficiency at the required frequency would be too low. Moreover, the higher operating anode potential would put undue electrostatic strain on the glass bulb with the existing structure. A new design has, therefore, been developed which overcomes the limitations of the earlier design and which is capable of full load operation up to 30 Mc/s.

The main electrode elements are the same as those in the CAT.17, but the method of supporting the grid and filament has been changed in such a way that the inductance of the grid and filament circuits has been considerably reduced and the glass bulb is protected from the high electrostatic field.

The new valve is made in two main parts: (*a*) The outer case, which consists of the anode, bulb and grid flange; (*b*) The grid and filament assembly, mounted on to a new metal header which includes a metal exhaust tube. These two parts are joined together at the rim of the grid flange and the metal header by heavy copper plating.

The metal header enables the grid to be supported by a tube of short length and large diameter which results in a very rigid structure of low inductance. The support tube affords complete shielding of the glass bulb from the filament supports which are taken through the centre of the tube.

Being both shorter and larger in diameter than those used in the CAT.17, the filament supports give the lower inductance required. The grid-to-filament insulation is provided by short glass tubes supporting the filament connecting terminal posts from the header, all of which is at grid potential. The general structure of the valve is seen in fig. 45. It is believed that, in due course, this new design will replace the existing valve for most radio frequency applications.

(8) Telecommunications, Radio and Valves

TELEPHONES.

A new uniselector rack (fig. 46) developed for the British Post Office enables economies to be made both in telephone lines and in floor space in the exchange. It accommodates 300 subscribers' line circuit units within overall dimensions no greater than those of the existing 200-line rack; moreover, as grading facilities are incorporated on the rack itself, a separate grading frame is not required. The lines may be operated either on an individual-subscriber basis or as a two-party-per-line arrangement with individual metering, the change from one to the other requiring only an alteration of connecting straps on the relay panels.

An emergency disconnect arrangement is provided, enabling outgoing calls to be denied to selected groups of subscribers during periods of excessively heavy traffic. Also two " home " positions are provided on the uniselector banks, with two corresponding first-choice connections to the first selectors in the exchange; this ensures service to subscribers during very low traffic periods despite a possible first selector fault.

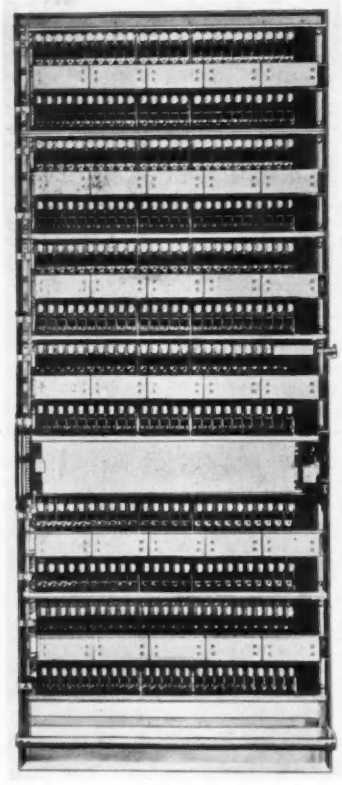


Fig. 46.—Uniselector rack developed for the British Post Office.

In the construction of much of the rack steelwork welding is used instead of the bolted-up method previously employed, thereby saving over 50 lb. of steel per rack without any reduction in strength. Rubber anti-vibration mountings minimise the possibility of microphonic noise occurring in the speaking circuits and, by simplifying the assembly, give easier access to wiring and mechanism.

For automatic telephone service to groups of subscribers in outlying districts some multi-party lines are frequently needed as well as the normal individual-subscriber lines, and hitherto a common numbering scheme for both could not be used; an extra digit has had to be dialled when calls are made to or from a party-line station. A rural party-line unit has now been developed which enables up to 20 multi-party lines, serving 100 subscribers, to be connected to a unit automatic exchange and incorporated in a common numbering system. One or more of these units can be operated with the U.A.X. and may be installed with the parent exchange or remote from it.

A special automatic exchange, 50/500 lines, has been developed to meet Admiralty requirements and will be used in the larger vessels of the Royal Navy. Unit construction is employed, with individual 50-line units enclosed in double-walled damp- and dust-sealed steel cabinets. It is noteworthy that, to meet the specified shock test, little variation from standard practice was necessary. A 500-line exchange has already been installed in the aircraft carrier " Eagle ".

The new S.E.50 two-motion selector, designed for maximum simplicity and stability of adjustment, is now in production, and initial deliveries have been made to various overseas administrations.

CABLE TRANSMISSION EQUIPMENT.

Development work on A.C. operated telephone transmission equipment employing compact plug-in panels has continued, and the 24-circuit

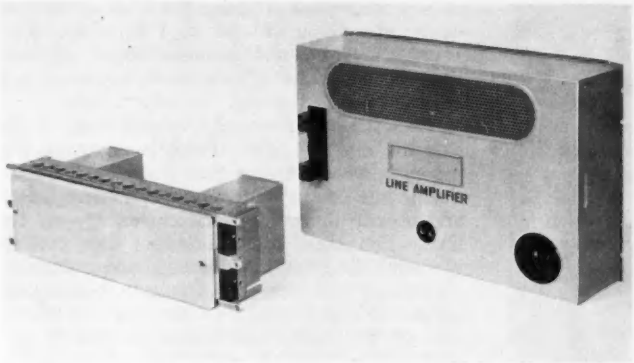


Fig. 47.—Line amplifiers for 12-24 circuit cable systems. The new design (*left*) is shown with an earlier type for comparison of respective sizes.

carrier system has been redesigned to embody this form of construction. Other apparatus of similar design includes terminal equipment for coaxial cable carrier systems and a new voice-frequency telegraph system, providing up to 24 duplex telegraph channels with lower distortion than in previous designs. The saving in space achieved by the new method of construction is clearly shown in fig. 47, which illustrates a typical carrier system amplifier in the old and new forms.

POWER LINE TRANSMISSION EQUIPMENT.

The type PA power line carrier system, which is now in production, is intended for use on small power distribution networks for which the type N multi-circuit system is uneconomical. The PA system provides one speech circuit and up to six signalling channels for telegraphy, supervisory control or telemetering. It employs a single carrier frequency in the range 80-200 kc/s and is designed for A.C. operation. The equipment may be mounted on one bay, or, as shown in fig. 48, on two bays complete with a stand-by rotary converter for operation from the station switching battery. Automatic switching is then used to change over to stand-by operation in the event of a power supply failure.

RADIO TRANSMISSION EQUIPMENT.

An excellent example of the use of multi-circuit trunk radio equipment for long distance telephonic circuits is provided by the V.H.F. system recently put into service by the Nyasaland Post Office. Extension of the trunk telephone service in Nyasaland has been hindered in the past by the difficulties involved in installing and maintaining lines in the mountainous country which separates the main population centres. Frequency modulated V.H.F. multi-circuit radio has enabled these difficulties to be avoided.

The network operates in the frequency band 70-88 Mc/s. It links the major towns in the Central and Southern Provinces and involves a total route length of over 330 miles, individual routes being covered by from one to three links. These vary in length from 34 to 59 miles and carry from three to twelve speech circuits. Between Zomba, the seat of Government, and Lilongwe, the administrative capital of the Central Province, there

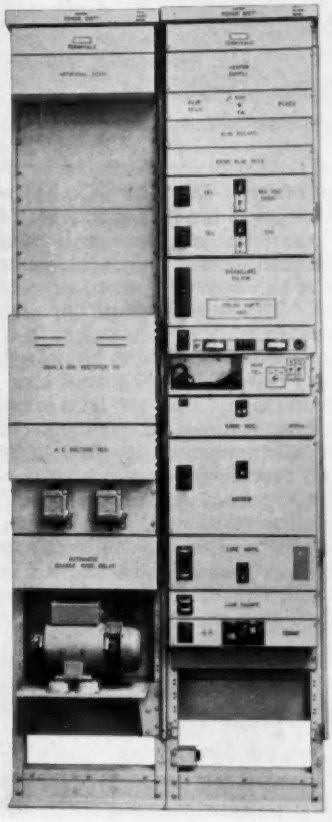


Fig. 48.—Type PA power line carrier equipment terminal bays; the power bay is on the left, the equipment bay on the right.

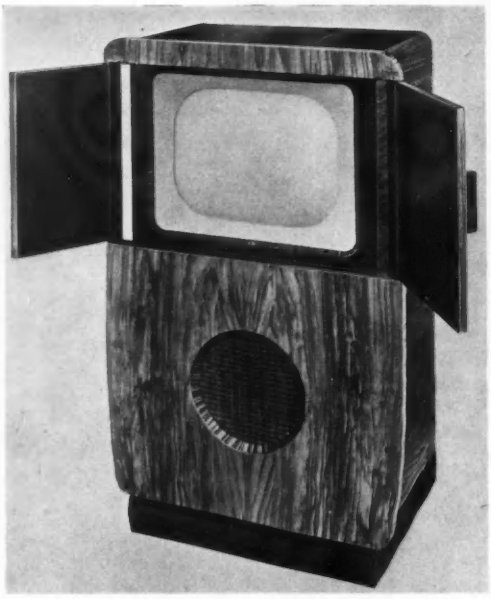


Fig. 49.—Console television receiver with 16 in. screen.

are three links with speech circuits between the terminals of each. In addition, both speech and duplex telegraph communication are provided between the route terminals. On all major routes 24-circuit multiplexing equipment facilitates expansion of the system to meet increased traffic demands. The freedom from impulsive noise enjoyed by frequency-modulated radio channels has been well demonstrated in Nyasaland, where very heavy seasonal thunderstorms have caused no interruption of service and little interference.

Two new versions of the compact F.M. junction radio equipment have been introduced. The first, providing two speech channels, employs rack-mounted equipment, a single rack carrying all terminal gear. The second, which has five speech channels each accommodating the frequency band 300-2,800 c/s, will be available in either rack-mounted or cabinet form.

TELEPHONE LIGHTING PROTECTION.

Many devices hitherto used for the protection of telephone equipment against induced voltage surges due to lightning have the disadvantage of short life. Experience has shown that, at best, they will handle only a few surges before developing a permanent short-circuit. Replacement is then necessary and this may present difficulties, particularly in remote parts of the globe where the maintenance engineer may have to cover a very large service area.

A small, two-electrode, gas-filled protector, easily manufactured and capable of handling many surges, has now been developed. It consists of a cylindrical glass capsule, sealed at both ends by a dished metal cap which serves both as electrode and terminal for connection to the external circuit. The filling is argon at low pressure, which ensures good glow-to-arc transition in the conducting state and hence efficient and speedy diversion of excess energy on the line. The small dimensions of the capsule protector, and the absence of the conventional pinch and pumping stem, make it particularly suitable in many instances where space is limited, not only in telecommunications but also in such applications as surge protection of measuring instruments and indicating light sources.

CATHODE RAY TUBES.

The 16 in. circular cathode ray tube for television is now in production at the factory, and rectangular tubes of 14 in. and 17 in. diagonal have been developed. All employ magnetic

Fig. 50.—Portable radio receiver for battery or mains operation.

focusing and deflection, have a 70° scanning angle across the picture diagonal and a neck of 38 mm. diameter. The screens are aluminised and allow operating potentials of up to 14 kV to be used with complete freedom from ion burn and from defects caused by poor secondary emission.

Monoscopes have been made for B.B.C. use at the new Wenvoe transmitter for picture signal generation. Flying spot scanner tubes have also been developed as an alternative, and perhaps more flexible, type of picture signal generator. These operate at about 30 kV and

are used in conjunction with a transparency and photo-multiplier.

Various specialised oscillograph tubes have been made, and tubes with conical deflectors are now in pre-production. By using these tubes with circular time-bases, and applying the signals to the central conical deflector, there is no time lost for the "fly-back" as on ordinary oscillograph tubes.

TELEVISION RECEIVERS.

G.E.C. television receivers in the new range incorporate the superhet technique, which enables the receivers to be made easily tunable over all five television channels. Besides the advantage to the user, manufacturing and distribution problems are greatly eased. Essentially, the main chassis follows the previous design but improvements in detail have been made including external focus control, a one-knob control of picture shift, and continuously variable noise suppression. The replaceable sub-deck mentioned in last year's Progress Article*, has been retained.

Circuit modifications have made the hold controls less critical in their adjustment and a line linearity control has been added.

As the major demand in normal domestic receivers continues to be for 12 in. tubes, two new models have been added to this category, and to meet the call for 16 in. models, receivers incorporating tubes of this size have been introduced. These are the BT6145 table version and BT6541 console (fig. 49).

* *G.E.C. Journal*, Vol. XIX, No. 1, p. 68, January, 1952.

Fig. 51.—High-quality radiogram.

A filter screen of truly neutral tint is now fitted as standard to give improved viewing in daylight or other high lighting conditions. Compact, single valve pre-amplifiers are available for use in areas of very low signal strength, and

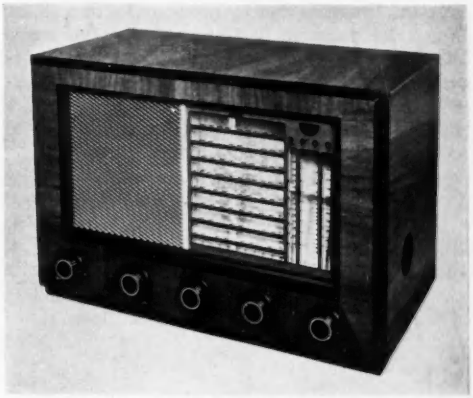


Fig. 52.—Export model radio receiver, for mains or battery operation.

provision is being made in all receivers for the amplifier to be easily fitted if required.

RADIO BROADCAST RECEIVERS.

The BC4444 portable receiver in a miniature suitcase (fig. 50) represents an entry into an entirely new market. The receiver operates from its own enclosed all-dry batteries or from any A.C. or D.C. supply mains of 200-250 volts.

Station pre-selection is a feature of a new table receiver, BC5839, and the same chassis is used in the high-quality radiogram, BC9835 (fig. 51) which also has a special push-pull output and twin loudspeakers. The BC9835 incorporates the latest type of record player operating at 33⅓, 45 and 78 r.p.m., with record-changing facilities at each speed. This also applies to the recently introduced BC9637 medium-priced radiogram which has a two-waveband receiver and single output valve and loudspeaker.

In the export field the main range of receivers continues to make use of the band-spread tuning technique described in the Progress Article for 1952*, comprising initial "detent" selection followed by auxiliary fine tuning. In addition, there is the BC2545 version operating from a 6 volt accumulator, which is one of a range of models available for all types of supply. A new technique is

* *G.E.C. Journal*, Vol. XIX, No. 1, pp. 69-70, January, 1952.

introduced with the BC2743 (fig. 52) which may be operated either from standard A.C. mains or from 6 volt accumulators, thus meeting the demand for a high-class receiver for alternative methods of operation.

The increasing call for all-dry battery receivers overseas has been met by the introduction of the four valve receiver BC1348 and the five valve BC1546, in wooden cabinets. Detail improvements have been made to the four-valve, two-waveband superhet receiver BC2147 and the metal cabinet has been altered to suit the requirements of particular markets.

RADIO COMMUNICATIONS.

Among equipment developed for special requirements for use on the V.H.F. band, the low power V.H.F. transmitter/receiver working in the range 78/184 Mc/s. is particularly noteworthy. It is specially designed for unattended operation in tropical countries, and is valuable to broadcasting authorities in linking studio to transmitter over a distance of several miles.

New fixed station transmitters, crystal controlled in the frequency range 70/184 Mc/s and with output powers of 100 and 250 watts, have been developed for mobile and point-to-point V.H.F. communication. They operate from 200/250 volts, 40/60 cycle A.C. mains. Forced air ventilation with dust filters is provided as a protection in severe climatic conditions. The BRT108 transmitter is shown in fig. 53.

For M.F. and H.F. operation a 150 watt crystal-controlled transmitter, particularly useful as a ground station beacon for aircraft, is now available and large quantities have already been supplied to overseas military authorities. Its excellent audio frequency characteristics make it suitable also for use as a low power broadcast transmitter where limited range is required.

MANUFACTURE OF COAXIAL CABLE.

Facilities for the manufacture of coaxial cable at Eastleigh Works have been increased. Three machines have been installed (fig. 54) capable of producing up to 20,000 yards a week of copper conductor supported coaxially in a formed copper tube by means of spaced polythene discs punched from strip.

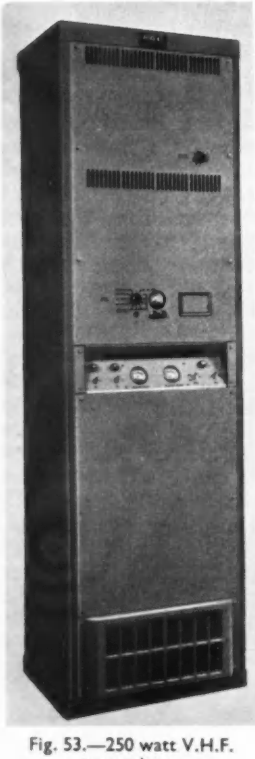


Fig. 53.—250 watt V.H.F. transmitter.

Fig. 54.—Manufacture of coaxial cable at Pirelli-General Cable Works.

Fig. 55.—Ribbon microphone.

with impedances of 15-30 and 300 ohms are also available.

A new 8 to 10 watt general purpose amplifier, the BCS2410 (fig. 57) has been introduced. It is designed for two fader-connected inputs, " microphone " and " music 1 ", with provision for an additional " music 2 " fader if required. The first stage input transformer is suitable for

Fig. 57.—General purpose amplifier.

SOUND EQUIPMENT.

The G.E.C. ribbon microphone, BCS2370 (fig. 55), a studio microphone with an extremely high standard of response, is a new addition to the range of sound equipment. It is suitable for use wherever specially high quality reproduction, with freedom from acoustic feedback, is desired. It is a velocity type microphone with a corrugated aluminium-alloy ribbon. A special pole piece assembly is used in conjunction with a high-flux magnet to provide an intense magnetic field, and three internal acoustic filters safeguard the instrument against possible damage from excessive voice pressures. The response (fig. 56) is substantially level from 50 to 14,000 c/s, and the microphone has a sensitivity of −72 db. at 1,000 c/s. A line transformer in the base of the case gives an output impedance in the standard model of 600 ohms. Alternative models any moving coil microphone of 15 ohms impedance, and a variable " bass cut " control operates on this stage. The " music 1 " input is applied via the mixing circuit to the second stage of the amplifier, which is followed by a phase-splitter feeding a push-pull output stage. The full rated output is provided at 60 volts and 20 volts by means of a tapped winding with connections to a terminal block at the rear of the amplifier. On the front of the chassis there is a mains on/off switch, and terminals for remote switching of the H.T. supply are at the rear.

A later version of the DA 100 power output panel BCS1238 (fig. 58) provides a power output of 100 watts largely under Class A conditions, or 175 watts under Class AB2, when it may be used for industrial sound systems where the very highest quality is not essential.

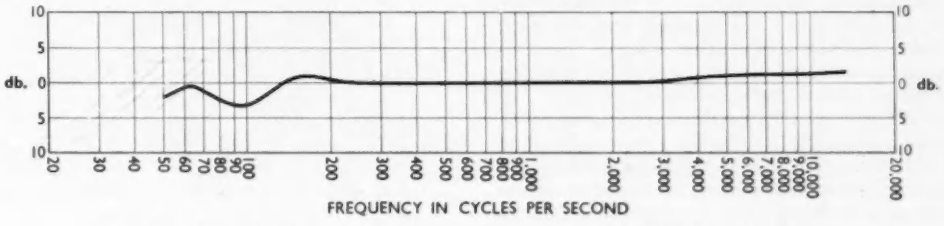


Fig. 56.—Curve showing axial frequency response of the BCS2370 ribbon microphone.

THERMIONIC EMISSION.

An interesting development for valves with flat oxide-coated cathodes is a method of flattening the coating surface by compression after spraying, which is of great value when very close grid-cathode clearance is required. The difficulty in maintaining the adhesion of the coating to the underlying metal during compression has been overcome by means of special treatments of the metal surface.

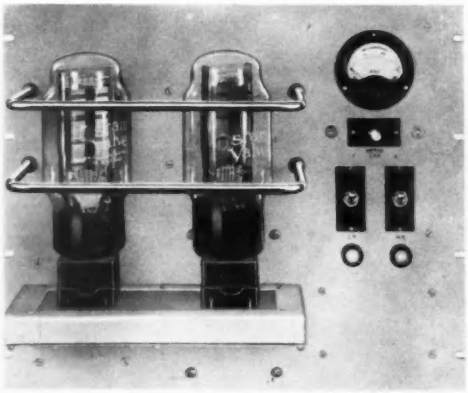


Fig. 58.—Amplifier panel.

The effect on emission of the method of applying the coating, and of the particle size, is being studied. Spraying is the most common means of application, but plating is also used, as well as the original process of drawing through a coating bath. The emission of coatings is being compared with that of thin evaporated films of barium and strontium oxides, not only as part of a fundamental study of these oxides, but also because the behaviour of such films is important in connection with grid emission.

Investigation of the decomposition of thin films of poorly conducting compounds under electron bombardment continues. It is found that decomposition begins at critical electron energies, depending on the physical and chemical properties of the films, and it is hoped that this knowledge will lead to a new method of examining valves with faulty emission. Comparison of the critical electron energy (measurement of which is not difficult) with the known behaviour of various types of film should facilitate identification of the films present on a faulty valve. Hitherto this could be done only after destruction of the valve.

VALVE LIFE-TESTING.

A considerable amount of work is being done at the present time in an attempt to improve the performance of radio valves used in aircraft and in other situations where severe vibration is encountered. One of the most important aids to this work is the machine for life-testing valves under known and repeatable vibration conditions. Fig. 59 illustrates a machine for life-testing B7G and B9A type valves under sinusoidal vibration conditions in the frequency range 50-500 c/s., with an acceleration of about ten times that of gravity. In this machine 24 valves are held in V-blocks cut in the vertically mounted tubular carriage. The carriage is supported by wires, and simple harmonic motion is produced by a moving coil motor, the coil being mounted directly on the lower end of the carriage.

Particular care has been taken to ensure that each valve on test is vibrated in exactly the same way as its fellows. If standing waves were present on the carriage, some valves would be executing different motions from others and would be differently stressed. It is especially important to avoid this when valve quality is assessed statistically, since where the number of defective valves during life-test is very small their

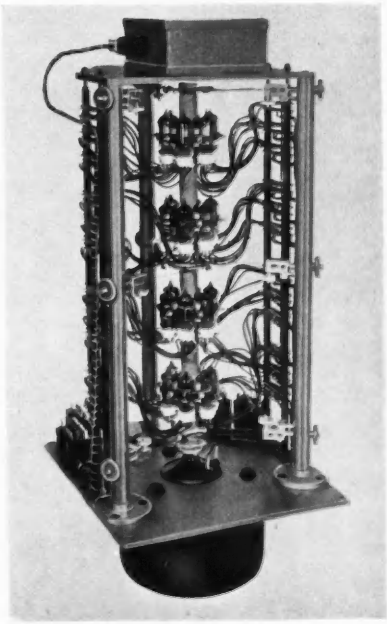


Fig. 59.—Machine for life-testing valves under sinusoidal vibration conditions.

statistical significance is correspondingly high. For this reason it is essential to have the assurance that any valve failure is caused by a defect in the valve itself and not by exceptionally severe life-test conditions applicable to that valve only.

CRYSTALS.

A range of very low frequency quartz crystals has been developed. They are of the bar type and cover frequencies from 400 c/s to 50,000 c/s. Single bar elements are used above 4,000 c/s, and double bar below that figure. The crystals vibrate in their flexural mode and have the characteristic frequency stability against time and temperature typical of crystals in the normal high-frequency range. They display high values of " Q " and inductance, and simple oscillator circuits have been developed which ensure both short starting time and correct limiting of drive amplitude. The double bar vibrators are of particular interest since it has been necessary to devise a method of bonding two quartz bars together without impairing their stability. The technique has recently been extended by making up experimental units in which the two elements are composed of several short bars. Multiple units of this type may be of great practical value should it become necessary to use small pieces of raw material.

Considerable success has attended research into the growing of quartz crystals for piezo-electric use. Crystals of high perfection, free from internal flaws and twinning, and weighing over 150 grams are now obtained readily in growing periods of about one month (fig. 60). When cut up, each crystal yields a large number of blanks for oscillator plates; in fact, these crystals are of optimum size for most requirements and larger ones need be grown only for special purposes. The temperature gradient method used for the synthesis of quartz involves the use of pressures in excess of 1,000 atmospheres at a mean temperature of about 380 degs. C., but the practical difficulties inherent in growing under these conditions have very largely been overcome.

CRYSTAL VALVES.

The present great interest in diodes and triodes made from semi-conducting materials has resulted in a considerable expansion of the long-term research being undertaken into the subject at the Research Laboratories.

It is only when these materials are in a high state of chemical purity that their desirable-electrical properties are obtained. For example, for certain special purposes the degree of impurity is less than one part in a hundred million, yet even then the actual amount of impurity present must be carefully controlled. Moreover, it has been found that in addition to the chemical impurities, defects in the crystal structure also play an important part in determining the electrical properties. It has been necessary to use

Fig. 60.—A typical synthetic quartz crystal.

single crystals of germanium for making crystal triodes, and also to study the effect of various heat treatments on the perfection of these materials.

Defects in crystal structure may also be introduced by the bombardment of high energy particles, and this phenomenon has been investigated. Usually the chemical impurities are introduced during the melting process but sometimes it is desirable to effect the introduction into the single crystal material after it has been grown. This can be done by diffusion. New techniques have been developed to study the diffusion rate and measure the various impurities in germanium.

In point contact rectifiers, not only must the semi-conductor material itself be carefully controlled, but also the state of its surface; consequently a considerable amount of study is being devoted to these surfaces and to the effect of various chemical treatments on their behaviour. Progress has been made in the development of germanium point contact triodes. Techniques have been evolved which make it possible to produce triodes of much better quality and reproducibility than hitherto, and small factory production has begun.

(9) Instruments

The A.C. load analyser shown in fig. 61 incorporates switchboard instruments of the new design described in last year's Progress Article*. It enables direct measurements of current, voltage, power and power factor to be made in three-phase circuits with a minimum of external connections, by means of the following meters:

(1) Three-range induction ammeter, 5, 25 and 125 amperes.
(2) Three-range induction voltmeter, 150, 300 and 600 volts.
(3) Double-element induction wattmeter with ranges from 1 to 100 kW; and
(4) Three-phase unbalanced load power factor meter.

The meters are of the long scale type, with 3½ in. dials and a scale length of 7¼ in., and are of B.S. First Grade accuracy. Switches are provided to change the voltmeter range and to insert the voltmeter and ammeter in each phase.

Fig. 61.—Portable A.C. load analyser.

Early experience with turbine supervisory equipment for measuring shaft distortion* has shown that it is essential to know the shaft speed if the information which the equipment supplies is to be interpreted correctly. Apparatus for indicating and recording this speed has therefore been developed. The indicating meter has two speed ranges: 0-3,000 r.p.m., to be used when the turbine is being run up from standstill, and 2,700-3,300 r.p.m., used during normal running. The recording instrument has a third range, 3,200-3,500 r.p.m., for use during overspeed conditions. A small, permanent-magnet high-frequency alternator is directly coupled to the turbine shaft and gives an output whose voltage and frequency are proportional to the shaft speed. On the 0-3,000 r.p.m. range the output is rectified and applied directly to the meter, but for the high sensitivity ranges it is fed to a network of series-resonant circuits. This enables large changes of output current to be obtained from only slight changes of speed. A pilot light shows the range on which the meter is indicating, the changeover from one range to another being entirely automatic. Changes of speed of 1 r.p.m. (one-sixtieth of a cycle of main alternator volt-

* *G.E.C. Journal*, Vol. XIX, No. 3, p. 170, July, 1952.

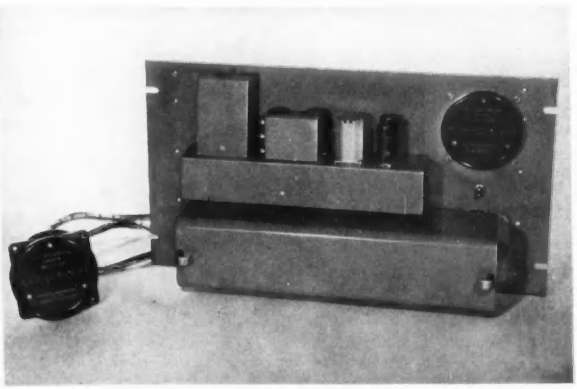


Fig. 62.—Self-balancing Wheatstone Bridge.

* *G.E.C. Journal*, Vol. XIX, No. 1, p. 60, January, 1952.

age) can be detected, and sensitivity to speed changes of 0·1 r.p.m. could easily be attained.

A considerable advance in the field of accurate remote indication of temperature has been made with the development of a self-balancing Wheatstone bridge for use with a platinum resistance thermometer: measurement to one-tenth of a degree C. is now possible over a range of 100 degress C. The bridge unit (fig. 62) employs a ten-stage reversible binary counter, by means of which resistances are switched into the balance arm until balance is obtained. A low-frequency alternating voltage is supplied to the bridge from an oscillator and the out-of-balance output is fed through a screened and balanced transformer to a phase sensitive detector. This consists of an amplifier and centre-stable polarised telegraph relay. When the bridge is unbalanced the relay makes contact on one side or the other according to the phase of the out-of-balance voltage, and causes the binary counter chain to count up or down to restore balance. The ten-digit binary code can be transmitted to a remote point by the electronic distributor described previously*, giving a temperature reading at any distance with an accuracy as stated above.

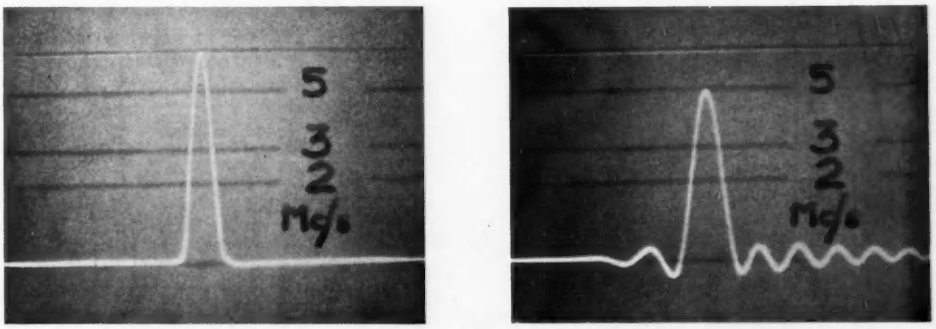


Fig. 63.—Sine-squared pulse of 0·1 microsecond width (a) before and (b) after passing through a 5 Mc/s low-pass filter.

Specialised instruments for laboratory use in connection with radio communications and

* *G.E.C. Journal*, Vol. XIX, No. 1, p. 67, January, 1952.

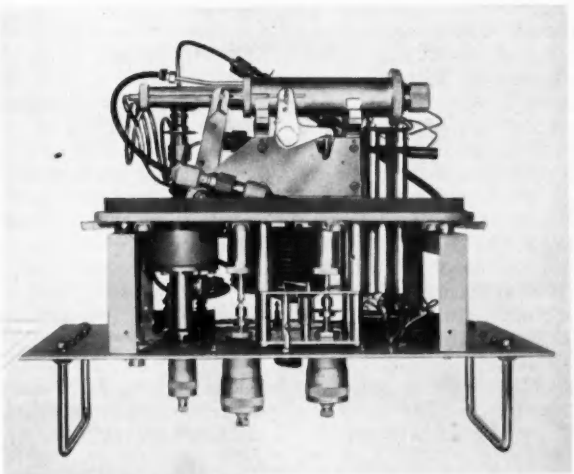


Fig. 64.—Interior of signal generator, 1,600-2,400 Mc/s.

television are continually being developed, and a few of these are described in the following paragraphs.

Apparatus has been built for the rapid testing of systems or equipment with low-pass filter characteristics and nominal upper cut-off frequencies of 3, 5 or 10 Mc/s. Pulses of sine-squared shape are generated, with a switched

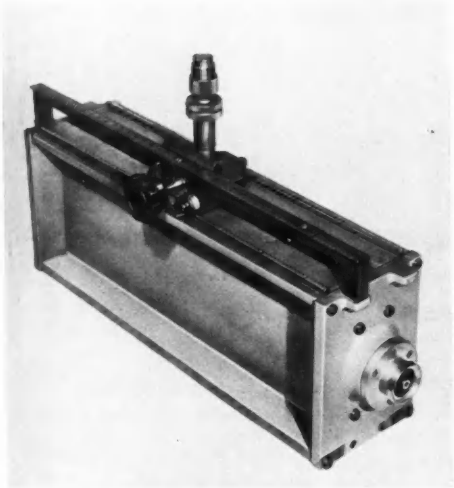


Fig. 65.— "Slab" line, used for constructing concentric standing wave lines.

choice of pulse-widths of 0·34, 0·17, 0·1 and 0·05 microsecond at half-height. The pulse is contained within one half-cycle of an accompanying square wave of the same peak-to-peak amplitude, the frequency of the square wave being switched to 30, 60, 100 or 200 kc/s. The signal amplitude is 0.4 volt peak-to-peak into 75 ohms.

After traversing the system that is being tested, the complete signal is amplified and applied to the vertically deflecting plates of a cathode ray tube. The square wave is extracted and integrated to give a triangular time-base wave to provide the horizontal deflection of the cathode ray tube beam. The trace is brightened during the forward stroke, the fainter return trace along the top of the display showing the initial pulse height. If group-delay distortion is small over the pass-band of the system being tested, the pulse displayed is symmetrical. The reduced pulse height gives a direct indication of cut-off frequency from a graticule calculated for ideal low-pass filters. A timing wave of 20 Mc/s is used when it is necessary to determine the ripple frequency or pulse width. Figs. 63 (a) and (b) shows a sine-squared pulse of 0·1 microsecond width before and after passing through a 5 Mc/s low-pass filter.

The signal generator (fig. 64) from a range of U.H.F. measuring equipment developed for use in the frequency band 1,600-2,400 Mc/s, uses a disc-seal triode valve in a coaxial line oscillator circuit. Tuning is by non-contact bridges moved by micrometer heads. The output is controlled by a direct reading piston attenuator, and output level is monitored by means of a directional coupler. Careful screening and decoupling reduces stray radiation to negligible proportions. For use with the signal generator, a superhet test receiver has been developed. It uses a similar oscillator, which is mounted with the mixer and intermediate frequency amplifier as a single unit. The band-width is 6 Mc/s and the noise factor 12 db.

A microwattmeter for measuring low powers within the U.H.F. band mentioned above consists of a direct reading power bridge of the substitution type. It has a maximum input of 120 microwatts, and is useful for standardising the output level of signal generators. A second compensating bridge is used to minimise the nuisance of drifts due to ambient temperature changes, giving an accuracy at maximum input of about $\pm$ 0 5 db.

One method of overcoming mechanical difficulties in the construction of concentric standing wave lines of high uniformity is the use of the so-called " slab " line. Good impedance uniformity has been obtained in the line shown in fig. 65. It may appear that the line is not well shielded, but, in fact, the field falls off very rapidly towards the edges of the " slabs " and a line such as that illustrated has a radiation equivalent to that of a concentric line with a very narrow slot indeed.

The adjustment of coaxial line filters is greatly accelerated by the use of the circuit response indicator. Apparatus of this type has been used at lower frequencies for some time, and its application to U.H.F. is largely a matter of technique. The indicator has a mechanical scanning arrangement, giving a scan of 100 Mc/s which may be centred anywhere in the frequency range of 1,700-2,300 Mc/s. Attenuation or coefficient of reflection characteristics are displayed on a cathode ray tube.

(10) Heating Equipment

A 25 kW edge gluing machine (fig. 66) has been added to the range of self-contained high frequency heating equipment designed for specific applications. It is used for the rapid gluing of strips of wood to make blockboards, and is generally similar to the 5 kW model described in last year's Progress Article*.

It is particularly useful where similar articles are to be continuously treated in a conveyor type oven. The controller can be used with dielectric heating generators of different ratings and, within the limit fixed by the maximum loading of any generator, it ensures that all articles passing through the oven are heated equally. It may be

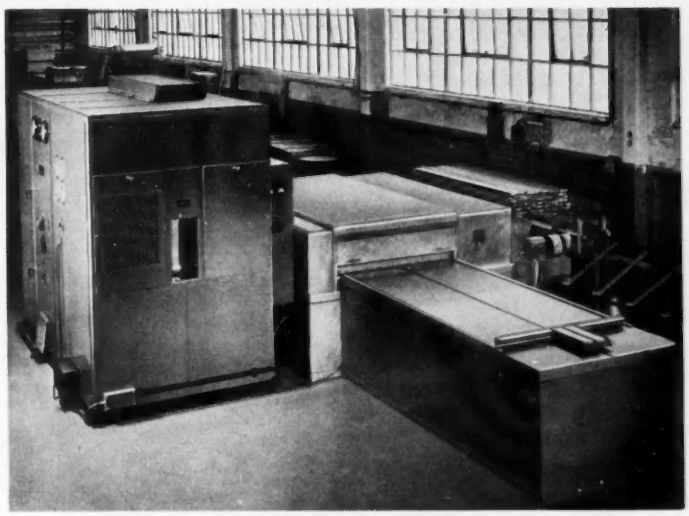


Fig. 66.—25 kW edge gluing machine.

After the glued strips of wood have been assembled on the loading table the subsequent operations, up to and including ejection of the made-up panel, follow automatically from a single operation of the control switch; thus while one panel is being heated the operator is free to assemble another. A controller fitted to the 25 kW high-frequency generator compensates for changes in the electrical characteristics of a panel while it is being heated, and ensures a high electrical loading throughout the cycle. Panels measuring 80 in. by 40 in. by 2 in. can be produced at a rate of 20 to 30 an hour, depending on the width of the individual strips used. Even higher production rates are obtainable for panels of smaller area and thickness.

An automatic load controller has been developed for use with dielectric heating ovens. pre-set to ensure the correct heating of different articles.

The sheathed wire element radiant heating unit was described in a previous Progress Article*. Since then many industrial ovens using this type of heater have been built and experience has shown their importance in the field of process heating. Sheathed wire element plants may be used in many processes as an alternative to infra-red lamp equipment, and in comparison with the infra-red lamp, the sheathed wire element is more robust and may be made to give a slightly higher intensity of heating. Most of the radiation it emits is of a longer wavelength than that from the lamp filament and in a spectral region where differences in absorptive power between pigments are much less than at shorter wavelengths. For this reason inequalities in

* *G.E.C. Journal*, Vol. XIX, No. 1, pp. 55 and 57, January, 1952.

* *G.E.C. Journal*, Vol. XVIII, No. 1, p. 64, January, 1951.

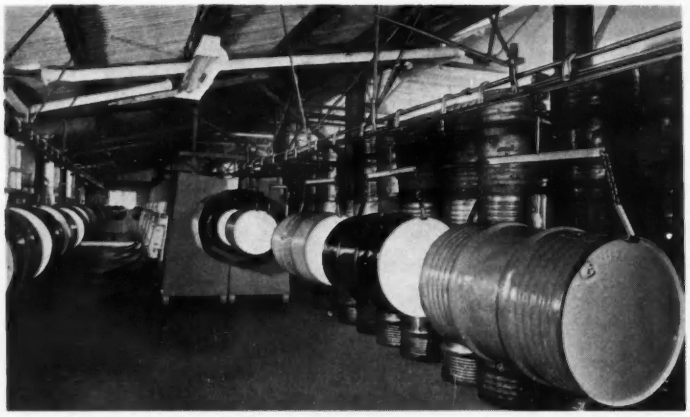


Fig. 67.—Sheathed wire element plant for stoving paint on reconditioned 40-gallon oil drums. The plant is 36 ft. long, has a maximum loading of 288 kW, and will handle 160 drums per hour with a stoving time of 3 minutes. (*Courtesy of Drum Reconditioners Ltd.*)

rates of heating sometimes experienced between surfaces of different colours, when using lamps, do not occur. A disadvantage of the sheathed wire element is that it takes a few minutes to reach its full operating temperature when switched on, and to cool when switched off, whereas the lamp filament responds practically instantaneously.

Examples of paint stoving plants using sheathed wire element heaters are shown in

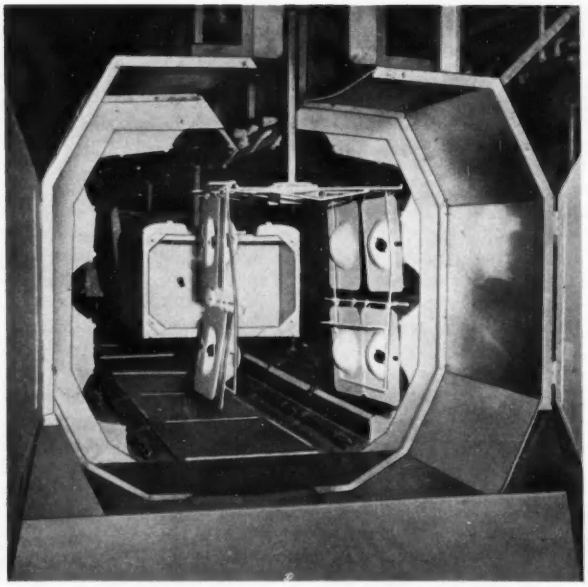


Fig. 68.—End view of sheathed wire element plant for stoving a high bake primer on refrigerator components. The plant is 21 ft. long and has a working loading of 175 kW. It handles 500 sets of components per 40-hour week.

figs. 67 and 68. The latter is particularly interesting since it shows part of an installation for the critical job of stoving refrigerator finishes. This plant is the second of three radiant heating units which stove the etch primer, high bake primer and finish coat on cabinets, doors and so forth, travelling on overhead monorail conveyors.

firing, and cooling down to handling temperature. Each of the three zones has an independently adjustable temperature controller. Information regarding the shape of the cooling curve is given by temperature recorders along the length of the firing and preheating zones.

The firing temperature of 800 degs. C. is

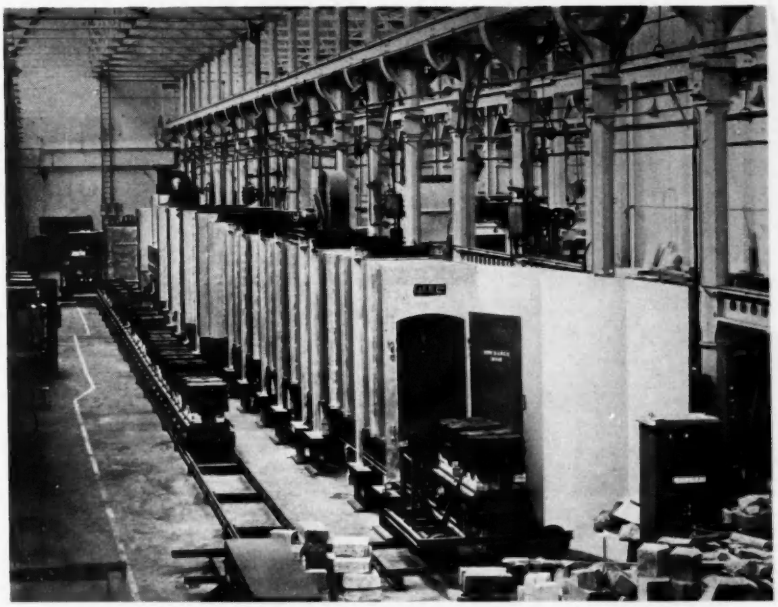


Fig. 69.—Kiln supplied for the Public Works Department of Entebbe, Uganda.

In it, high bake primer is heated to 250 degs. C. in seven minutes.

A kiln (fig. 69) for the manufacture of roofing tiles from local material has been completed by the Furnace Department at Fraser and Chalmers for the Public Works Department of Entebbe, Uganda. The placing of this order was one of the first results of electrical power becoming available in Uganda.

The kiln has a cross section (or placing width) of 18 in. wide by 36 in. high. It has been designed for an output of 6,600 tiles per 24-hour day, and is of the continuous type in which the charge is carried through on refractory faced trucks, the tops of these forming the base of the furnace chamber. There are 22 trucks which occupy the full length of the furnace, and three spares for loading. Each truck carries about 300 tiles. Operation is based on a definite thermal cycle including periods for preheating, automatically controlled. The total rating of the kiln is 300 kW, arranged as a balanced load on a 440 volt, 3-phase, 4-wire supply. Elements are of the coiled type, carried on each side wall and connected through 3/2 phase transformers in order to obtain an electrical balance in each of the three zones. Excess-temperature fuses are used for protection. These operate through the main oil circuit breaker and, in the event of failure of the operating thermocouples, the excess-temperature fuse will open the main supply at the breaker.

The trucks are sent through the furnace end to end by means of hydraulic pusher gear. The forward movement of the ram is equivalent to the length of one truck, and after withdrawal a further truck is inserted from the transverse track. Thus the charging of a truck causes a fired load to be discharged at the exit end, where the trucks are unloaded, swivelled on a turntable,

loaded on the return track and pushed forward ready for recharging.

A new range of water boiling urns (fig. 70), suitable for use in catering establishments, has been produced. They are made in 3, 6 and 10-gallon sizes, with loadings of 3, 6 and 9 kW respectively, and are constructed of heavy gauge copper with tinned interiors. Heating is by sheathed wire immersion heaters, each of which has its own push-button re-set safety cut-out device as protection against failure due to boiling dry. The elements are easily replaceable, access to them being obtained through removable covers (fig. 71). Each urn has three-heat control by rotary switches.

Fig. 70.—One of the new range of water boiling urns.

Humidifying units (fig. 72), designed to provide a comfortable atmosphere in the pressurised cabins of aircraft flying at high altitudes are being supplied for installation in Bristol " 175 " (Britannia) aircraft. Steam from the electrically-heated boiler of the unit may be fed into the cabin air supply at any convenient point by means of a 2 in. diameter pipe provided for the purpose. Water is fed by a pump into the boiler through an automatically-controlled float chamber. Should the water level in the chamber fall because of failure in the feed, the heating elements are automatically cut out. The unit is controlled by a hygrostat which comes into operation when the relative humidity falls to 25 per cent and cuts out at between 60 and 70 per cent.

The boiler, which has a capacity of about $1\frac{1}{2}$ gallons, has ten pocket tubes mounted in a removable apparatus plate. Each tube accommodates one 750 watt cartridge type element, thus giving a total loading of 7·5 kW. The number of elements may be varied to give any desired loading up to the total, and this may be increased to 10 kW by slightly increasing the overall length of the unit. Heaters to operate on 112 to 250 volts A.C. or D.C. can be accommodated. The 7·5 kW and 10 kW loadings generate about $19\frac{1}{2}$ lb. and 26 lb. of steam per hour respectively. The standard unit weighs 32 lb. and measures overall $18\frac{3}{4}$ in. long by $10\frac{3}{4}$ in. high to the top of the steam pipe.

Fig. 71.—Detail view with cover removed giving easy access to elements.

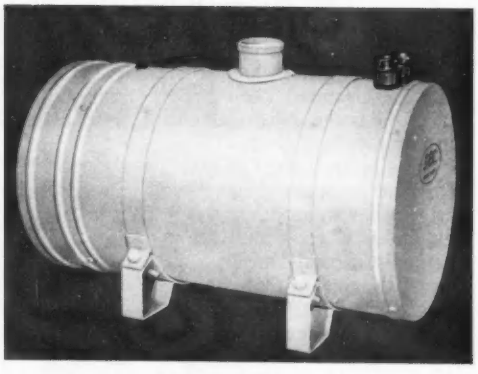


Fig. 72.—Humidifying unit for use in aircraft at high altitudes.

(11) Lamps and Lighting

FLUORESCENT TUBES.

Automatic machinery for producing circular fluorescent tubes has been constructed, enabling the Osram Circle (fig. 73) to be put on the market. It is a 4 ft., 40 watt "Mellow" tube bent into a circle of 16 in. overall diameter, the ends of the tube being joined by a plastic cylinder incorporating four recessed contacts. Normal 40 watt control gear is used, but a special instant start circuit is in an advanced state of development.

As the Circle is likely to be used in locations where no earth point is available, the earthed starting strip as used on straight tubes is dispensed with. Instead, an insulated conductor is attached to the fitting and arranged to run close to the tube. The conductor is connected to the neutral mains lead and, to ensure reliable starting under adversely humid conditions, the tube is treated with a hydrophobic coating of silicone.

In recent years considerable emphasis has been placed on the life performance of the fluorescent tube. The life of the tube depends almost entirely on the cathode, but it was impossible to take advantage of cathode improvements until the discovery and development by the G.E.C. of the halophosphate powders. These have excellent lumen maintenance characteristics, and the increase in life resulting from their introduction has led to further study of the dark deposits which occur near the electrodes of fluorescent tubes after a few thousand hours' burning. This work has been so successful that the modern fluorescent tube has a clean appearance for most of its useful life.

Efforts to develop a fluorescent tube colour suitable for lighting for social occasions have resulted in a colour very similar to that of the tungsten filament lamp both in appearance and rendering. This has been achieved by using a selective filter between the fluorescent coating and tube wall to control the blue and purple lines of the mercury spectrum.

MERCURY LAMPS.

The new phosphor with deep red fluorescence, mentioned in last year's Progress Article*, is of barium-strontium-lithium silicate composition which has been found particularly suitable for use in quartz high-pressure mercury vapour lamps. It has little or no body colour and is far less temperature sensitive than the sulphide materials used in existing lamps of this type. The new phosphor also has a broad excitation band extending over both the short and long wave U.V. regions. An improved 125 watt quartz mercury vapour fluorescent tube has therefore been designed, having a smaller outer jacket than the present type and about double the red light emission. The colour is a good white, free from any yellowish tinge, and the appearance of the unlit lamp is also pleasing.

Fig. 73.—Osram Circle.

TUNGSTEN FILAMENT LAMPS.

The British Standards Institution Lamp Committee has agreed that the efficiency requirements of general lighting service lamps of 25 to 200 watts inclusive should be increased by 3 per cent, both in initial light output and lumens throughout life. It has also been agreed to change the bulb size of the 60 watt G.L.S. lamp to enable the same bulb to be used as for the 40 watt lamp. This change will result in a gain in productive efficiency, more economic use of components and packing materials and a reduction in distribution costs.

The practice of incorporating fuses in the leads of coiled coil lamps to check arcing on failure has been found so successful that the principle has now been extended to Osram single coil lamps in wattages from 40 to 300.

Special Osram cycle dynamo bulbs have been produced with the object of providing

* *G.E.C. Journal*, Vol. XIX, No. 1, p. 44, January, 1952.

(*i*) simplified focusing, and (*ii*) a more evenly distributed beam. Practically all cycle lamps use a paraboloidal reflector, making it essential for some part of the light source to be at the focal point if a black spot is to be avoided. The accurate focusing which is therefore necessary is difficult with the normal 6 volt low amperage filament, but the new granulated bulb increases the virtual light source so that there is a bigger tolerance in focusing before a black spot results. The granulated bulb also smooths out the striations which may always be seen when a clear bulb is used.

Fig. 74.—One of the new solid-filled chokes for use with discharge lamps.

The principle of differential filament spacing has been applied to the low voltage 750 watt Class A1 projector lamp. By making the gap between the central and outer vertical limbs of the filament smaller than that between the central limbs, a more uniform distribution of temperature and brightness is achieved.

A new optical pyrometer lamp has been developed having a bulb made of a short length of tubing with an optically flat glass disc at each end. The discs are placed at an angle to the tube axis so as to eliminate the possibility of filament images appearing in the vicinity of the filament itself. This will avoid the slight inaccuracies in temperature measurement that were likely to arise due to filament image distortion in existing lamps of this type.

ISOTOPE LAMPS.

In collaboration with the National Physical Laboratory, the G.E.C. Research Laboratories have continued the development of a mercury isotope $^{198}_{80}Hg$ light source in the form of an electrodeless lamp capable of excitation by means of a high-frequency oscillator. The presence of a carrier gas in a metal vapour discharge lamp causes an asymmetrical broadening of the spectral lines, with consequent wavelength shift, and this is a considerable disadvantage in high retardation interferometry. Recent advances in lamp processing techniques have, however, made possible the manufacture of long-life electrodeless lamps which contain little or no carrier gas, but yet have a high degree of freedom from contamination due to residual impurities.

The spectral output of the new lamps shows an absence of the pressure broadening effect, and it has thus been possible to make a quantitative assessment of the change of wavelength of the spectral lines with carrier gas pressure. At a carrier gas pressure of 0·25 mm. Hg, i.e. 8 per cent of its former value, wavelength shift and broadening due to pressure are negligible, and lamps containing this filling are accepted by the National Physical Laboratory as the best source of $^{198}_{80}Hg$ radiation at the present time.

GERMICIDAL LAMPS.

Some experimental germicidal lamps have been produced with which it is proposed to extend the scope of research in this field. They incorporate a special glass with high transmission in the short wave ultra-violet region.

DISCHARGE LAMP AUXILIARIES.

A new range of totally enclosed solid-filled chokes (fig. 74) is available, with special fillings

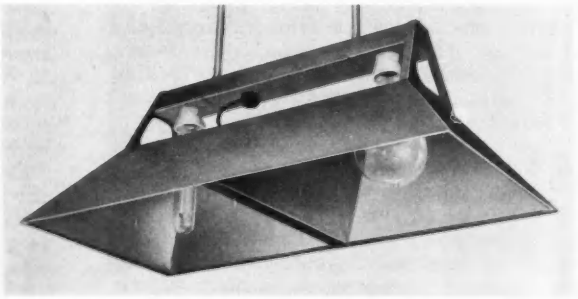


Fig. 75.—Blended-light fitting for industrial use.

which provide adequate protection against moisture and dust. The entire voltage range is covered in 7-volt steps and the settings always remain constant.

Chokes for the new 1 kW high bay H.P.M.V. lamp are in production, and two new control units, one for single-lamp and the other for double-lamp operation, have been designed for the instant starting of 4 ft., 40 watt fluorescent tubes. The control units incorporate capacitors for power factor improvement and suppression of radio interference. A new air-cooled transformer for the instant starting of the Osram Circle has also been developed.

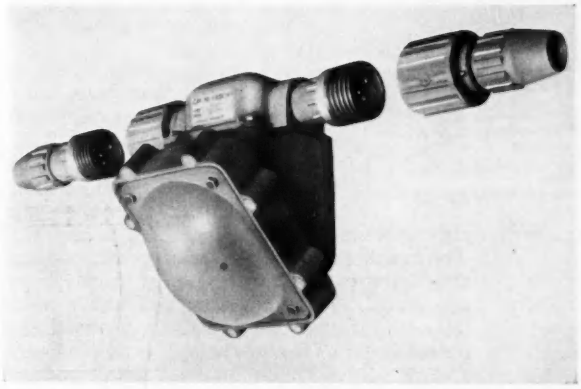


Fig. 76.—Coal face lighting fitting for use with a 60 watt filament lamp.

The auto-connected strayfield transformers for 120 watt, 8 ft. fluorescent tubes, and air-cooled chokes for 400 watt and 250 watt H.P.M.V. lamps, have been improved to obtain more effective use of materials and a consequent reduction in the size of the units. Also, the solid-filled 140 watt and 85/60/45 watt strayfield transformers for sodium lamps are now equipped with 10 volt mains voltage tappings and operate at an improved power factor.

GLASS MANUFACTURE.

Production of machine-drawn W.1 tubing has now begun at Lemington Glass Works. Previously this had been drawn by hand, and the new method gives greater uniformity of diameter and wall thickness. A method of enamelling 5 ft. lengths of soda glass tubing for the manufacture of architectural lamps has been developed, and this is another process now in regular operation.

NEW LIGHTING EQUIPMENT.

High-pressure mercury vapour lamps are still preferred to fluorescent tubes for many industrial lighting installations, and a blend of mercury and tungsten filament lighting is proving popular where reasonable colour-rendering is required. The new fitting shown in fig. 75 accommodates one lamp of each of these two types. They are housed in separate rectangular aluminium reflectors designed to give an even blend of light. The control gear for the discharge lamp is housed between the reflectors, which are easily removable for cleaning.

The development of flameproof equipment has continued. Fig. 76 shows a new type of fitting for coal face lighting which houses a 60 watt filament lamp and incorporates a flat " armour-plate " front glass. A domed opal " Perspex " outer cover has been added to diffuse the light. A number of these fittings in service below ground is seen in fig. 77. Another

Fig. 77.—Coal face lighting in the Birch Coppice Colliery of the National Coal Board.

new flameproof fitting (fig. 78) houses a 5 ft. 80 watt fluorescent tube and its control gear. This fitting is much lighter in weight than previous designs, and gives simpler and quicker access to the lamp. Baffles incorporated near each end limit the pressure wave to a safe value in the event of internal ignition.

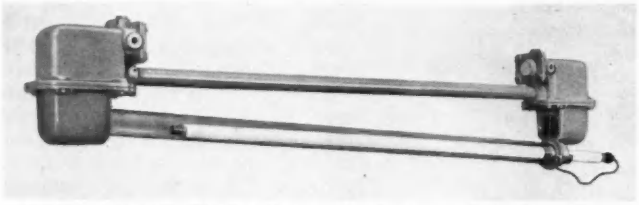


Fig. 78.—Flameproof lighting fitting, showing ease of changing tubes.

New fittings have also been developed for use in hospitals. Fig. 79 shows a ward with general lighting provided by open box-like fittings accommodating fluorescent tubes and small filament lamps for low level night lighting. A new type of wall light has been produced in which the lamp is backed by a specular aluminium reflector giving a strong light downwards at about 45°. A curved opal "Perspex" shade, open at top and bottom, softens the forward light to avoid possible discomfort to patients on the opposite side of the ward.

The latest design of fitting for use over operating tables is shown in fig. 80. As in earlier types, a 150 watt filament lamp is the principal light source, but the light is now controlled by a highly specular spun aluminium reflector instead of glass mirrors. This gives greater accuracy of contour and has enabled the illumination in the high intensity patch to be increased to some 2,000 lumens per square foot, about four times greater than before.

A plant illuminator for stimulating growth has been introduced, based on experiments carried out by Mr. W. J. C. Lawrence, V.M.H., of the John Innes Horticultural Institution. So far, mainly tomatoes and cucumbers have been treated (figs. 81 and 82). The health and vigour of seedlings were noticeably improved and their rate of development accelerated. Earlier maturing and heavier yields followed; treated tomato plants flowered and fruited about a fortnight before normal and were a truss ahead. The practical result was an increase of about 60 per cent in early fruit yield.

LIGHTING INSTALLATIONS.

Among many lighting installations supplied are several employing the continuous trunking system for fluorescent lighting. One such is in a large industrial drawing office illustrated in fig. 83. The installation of cold cathode lighting at the Heaton Works of C. A. Parsons & Co. Ltd., has been ex-

Fig. 79.—Ward lighting installation at the Royal Surrey Hospital, Guildford, comprising fluorescent tubes, and filament lamps for night lighting.

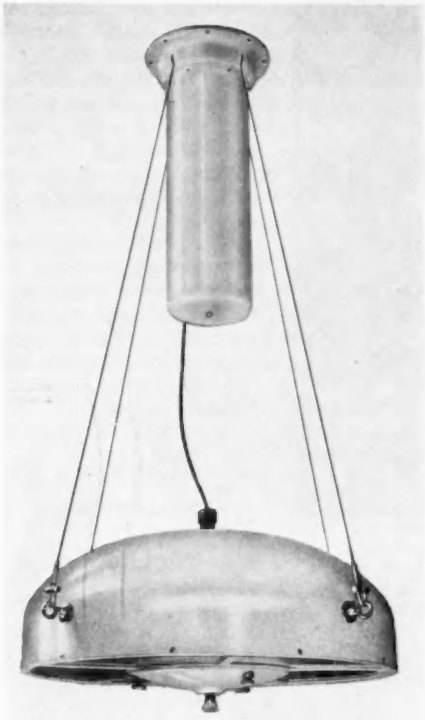


Fig. 80.—Operating-table lighting fitting, housing a 150 watt filament lamp.

tended, and now includes some 27 miles of cold cathode tubing, believed to be the largest installation of its type in the world. A laboratory in the Works where the tubes have been accommodated in the ceiling in a novel manner is illustrated in fig. 84.

An interesting fluorescent lighting scheme in a large banking hall is illustrated in fig. 85. The customary pendant fittings have been eliminated by the use of specially designed fittings giving both upward and downward light; as they are supported over the desks they give high intensity on the working plane in addition to well-diffused general lighting. The fittings are equipped with louvres in both the upper and lower apertures, the former to avoid discomfort to clerks working in the mezzanine gallery.

Fig. 82.—Effect of plant illuminator. Treated and untreated cucumber plants; sown 2/12/51, photographed 15/2/52.

Fig. 81.—An installation of plant illuminators.

EXTERIOR LIGHTING.

New lanterns for use in side roads have been designed, with die-cast light alloy bodies. In these lanterns the dome refractor is secured by stainless steel spring clips which engage with a lip on the top inner edge of the refractor. The prismatic surface is thus left unobstructed to facilitate cleaning. Alternative optical systems are available: the "Wembley" type, comprising a dome refractor and an outer bowl of "Perspex" or clear, rimpled or white opal stepped glass; or the "Oxford" type, having the dome refractor and a prismatic outer bowl refractor. Lamps may be tungsten filament 60-200 watts, or mercury vapour 80 or 125 watts.

Lamps of the same types and wattages are used in the cast-iron "Brookvale" lantern

Fig. 83.—A typical installation of the continuous trunking system of fluorescent lighting.

(fig. 86), which follows constructional principles similar to those of the lanterns described above.

For sodium lighting in side roads the lantern shown in fig. 87, which houses a 45 or 60 watt sodium lamp, is a simple but effective unit. It consists of a one-piece, open, inverted "Perspex" bowl, to the sides of which are bonded "Perspex" refractor plates. The almost exclusive use of plastics in its construction results in exceptional lightness.

Also for use with a 45 or 60 watt sodium lamp, for side-road lighting, is the new totally enclosed top-entry lantern shown in fig. 88. Space is provided within this lantern itself for all the necessary auxiliaries when they cannot be accommodated in the base of the column. The lantern body is a single-piece aluminium alloy

Fig. 84.—Part of an installation of cold cathode lighting in the new office block at the Works of C. A. Parsons & Co., Ltd. The whole installation is believed to be one of the largest of its type in the world.

die-casting, and the lamp is enclosed by a " Perspex " bowl with sealed refractor plates.

Fig. 89 shows a lantern of particularly attractive appearance, intended for side-road lighting but also suitable for promenades, public gardens, space lighting in front of offices, halls, blocks of flats, and similar areas. It uses a tungsten filament lamp of 60/200 watts or a mercury lamp of 80 or 125 watts, and is available with the " Wembley " type of optical system described above.

A new side-road lantern for use with two 2 ft. fluorescent tubes of either 20 watts or 40 watts rating has been designed. It is an alternative version of the well-known " Two-forty " lantern, from which it differs in that the totally enclosing " Perspex " bowl carrying the refractor plates is shallower in the new model. The lampholders are mounted directly on to the inner surface of the bowl to ensure positive location of the lamps in relation to the refractor plates. Lamp auxiliary gear is housed within the lantern.

For main road lighting several new designs of lanterns have been introduced and improvements made to existing types. The " Universal Dioptrion " lantern, for example, has been the subject of numerous modifications including the complete redesign of the toggle catches which secure the lower refractor to the upper. A new gasket of special section has also been adopted.

Fig. 86.—" Brookvale " lantern with outer bowl refractor.

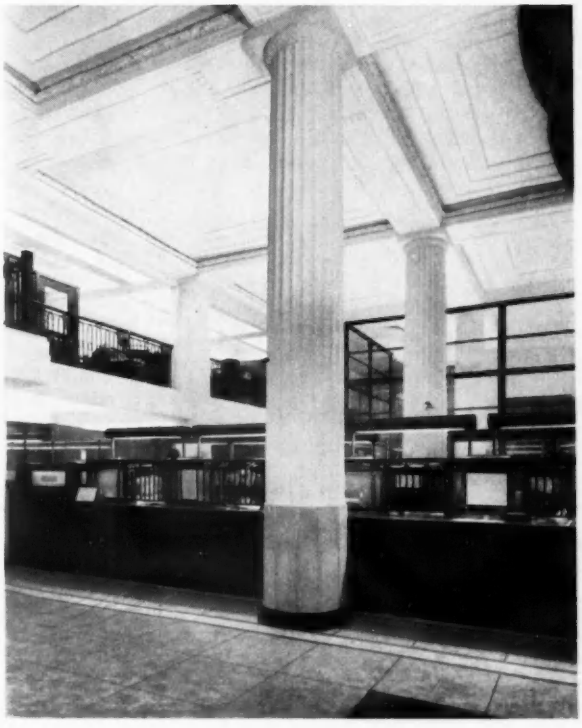


Fig. 85.—Fluorescent lighting in a banking hall, showing use of bench-supported fittings.

A new main-road lantern for use with an 85 watt or 140 watt sodium lamp has been introduced. It has a die-cast light alloy body and a totally sealed " Perspex " optikon. Provision is made for housing all lamp auxiliary gear within the lantern.

The " Four-eighty " lantern is an addition to the extensive range of main-road fluorescent tube lanterns using " Perspex " refractors and carrying all the necessary lamp auxiliary gear within the lantern.

Cut-off lanterns have been used in a number of notable street lighting schemes, and an example is shown in fig. 90. This is a downhill view of an installation in Ladbroke Grove, Kensington, where " Three-eighty " cut-off

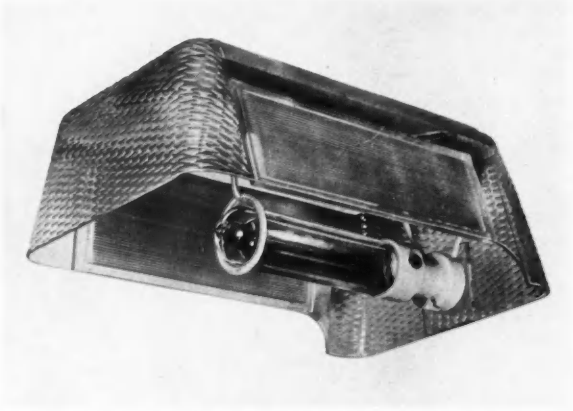


Fig. 87.—Open lantern for side-road lighting with sodium lamps.

lanterns are used. This lantern has been developed, largely for use overseas, to light wide roads bordered by heavy trees. The lanterns in the scheme illustrated are spanwire suspended down the centre of the carriageway at a height of 27 ft. and at an average spacing of 105 ft. The dark patch in the background is beyond the installation.

Cut-off lighting is particularly suitable for roundabouts since the number of lanterns that can be seen simultaneously is reduced, thus avoiding confusion to approaching drivers. Fig. 91 shows an installation using 250 watt mercury lanterns.

Recent installations of fluorescent street lighting in Belgium made use of very simple lanterns with opal " Perspex " diffusing envelopes and no refractors, spacing being closer than is customary in England. The results seemed so successful that it was considered possible that, at such small spacing, simple diffusing equipment might give results just as good as do the more expensive refractors. Accordingly a test was made of the lighting effect of a single lantern using :

(*i*) a diffusing envelope, and

(*ii*) a prismatic light-controlling envelope.

Figs. 92 (a) and (b) show some of the results obtained. The road

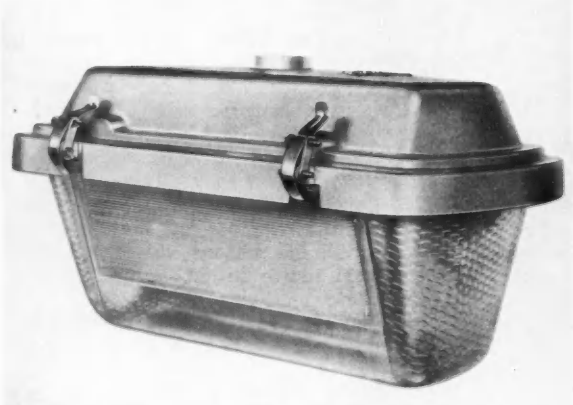


Fig. 88.—Enclosed lantern for sodium lighting in side roads.

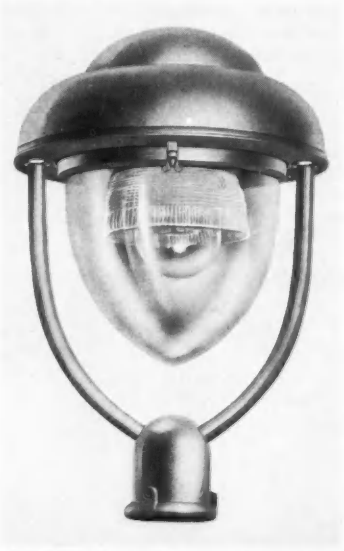


Fig. 89.—Side-road lantern also suitable for promenades and other public spaces.

became damper during the tests, favouring the prismatic envelope, but it was possible to measure this effect and allow for it. Calculations from the corrected results showed that in a complete installation the prismatic envelope would give a road surface brightness some 2½ times greater than the diffusing enclosure, with improved revealing power and an only just perceptible increase in discomfort glare. Confirmation by direct tests on a complete installation would be desirable, but it can be concluded that there are substantial advantages

Fig. 90.—Fluorescent street lighting in Ladbroke Grove, London, using "Three-eighty" cut-off lanterns.

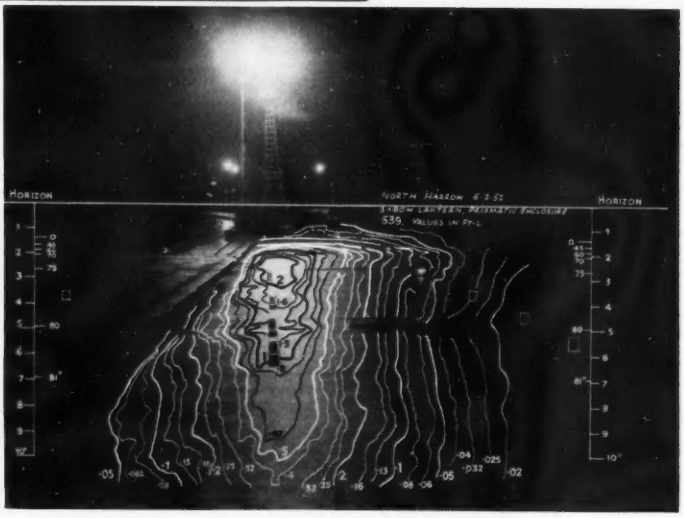
in the proper control of light even at the short spacings used on the Continent.

AERODROME LIGHTING.

A modified version of the helicopter unit designed to provide (*a*) a homing beacon; (*b*) a landing area floodlight; (*c*) a wind direction indicator, has now been developed for use in war areas. It is mounted on a collapsible aluminium tripod about 4 ft. high, and the whole apparatus, including accumulators, can be carried and erected within a few minutes by two men. It comprises a prismatic beacon light beneath which is an optic which floodlights a circle of about 100 ft. diameter, within which the pilot of an approaching helicopter can choose his landing point. He may also note wind direction with the aid of a radial shadow cast on the area; this is produced by means of a wind vane carrying a narrow shadow bar which rotates about the

Fig. 91.—Roundabout lighting at Twickenham using "blown glass cut-off" lanterns housing 250 watt mercury lamps.

Fig. 92 (a) (*above*).—Single "Three-eighty" fluorescent tube lantern, 25 ft. high, 200 ft. distant, on slightly damp asphalt surface. Contours show luminance (brightness) of surface in ft. lamberts. Diffusing enclosure.



(b) (*right*)—Single "Three-eighty" fluorescent tube lantern, 25 ft. high, 200 ft. distant, on damp asphalt surface, slightly damper than (a). Contours show luminance (brightness) of surface in ft. lamberts ; values are somewhat higher than they would have been with same conditions as in (a). Prismatic enclosure.

and Bar method is impracticable. It has been improved by the addition of two winglights in line with the rotating beacons to give guidance in roll, the sensitivity has also been increased by adding a third light between the other two, timed to flash at the instant when the two beacons come on track.

There has been a marked tendency towards the use of elevated types of runway lights, and a new uni-directional, high intensity unit has recently been introduced together with an approach light vertical axis of the unit. When the helicopter is near, the unit on top of the beacon is replaced manually by another light showing red or yellow to indicate if the angle of descent is too steep or too shallow.

About sixteen years ago the Research Laboratories devised a counter-rotating beacon for the guidance of approaching air pilots. It consisted of two beacons placed side by side, rotating in opposite directions, and arranged so that their beams intersected on the intended track. The system has recently been revived with the intention of using it in situations where the Line which is, in several respects, similar. Military and civil specifications for such equipment require that it should be light both in weight and construction so as to minimise possible damage to aircraft and other vehicles in the event of collision.

The high intensity runway light, illustrated in fig. 93, is a light weight unit suitable for ground mounting on a cast-iron plate. It can be used with low-voltage lamps of from 36 to 100 watts, and with the 100 watt lamp gives a light distribution with a peak intensity of approximately 40,000 candelas. The beam widths to half this

value are 13° horizontally and 4° vertically. A super-purity aluminium reflector is incorporated, into which is lapped the pressed, heat-resisting spreader glass.

The high intensity approach light, which is constructed in a very similar manner, is suitable either for a low-voltage 200 watt lamp for use on series circuits, or alternatively with a mains voltage 250 watt lamp. With the mains voltage lamp a peak intensity of 55,000 candelas is obtained with horizontal and vertical beam widths of 12° and 7°. The light is particularly suitable for use on that part of an approach lighting system nearest to the runway end, since in an area depending on the runway dimensions and other local conditions known as an "over-run" any lights liable to cause an obstruction are avoided.

As a result of experimental work connected with the manufacture of pressed coloured glassware, a red prismatic dome has been developed and is now being fitted as standard on G.E.C. single and double obstruction lights (fig. 94). It has been designed to increase the light intensity between the horizontal and 20° above, this being the zone in which the greatest range is required. The outside contour of the dome is smooth, in order to make the most of the cleansing effect of rain.

Fig. 93.—High intensity runway light.

ILLUMINATED DISPLAY PANEL.

A new type of sign intended for use in shop windows, on counters and in similar display positions is being marketed by Claude-General Neon Lights, Ltd. It is equipped with letters formed of 6 mm. glass tubing individually mounted on bakelite holders with small built-in magnets. The magnets enable the letters, which are available in several colours, to be attached to an iron plate forming the background of the sign; the letters are thus easily interchangeable. The sign is available in several sizes. On the most popular, 24 in. by 19 in., a message of about fifty 1½ in. characters may be accommodated. The whole sign, including the power pack, is self-contained and ready for connection to any A.C. supply. Consumption is only about 100 watts and there is no interference with radio reception.

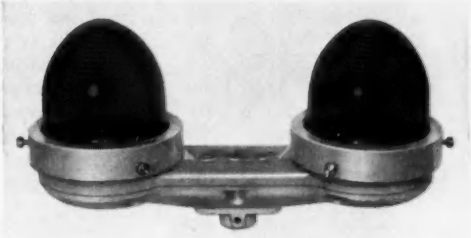


Fig. 94.—Double obstruction light using red prismatic domes of pressed glassware.

The Design of Street Lighting Lanterns

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G.E.C. Research Laboratories.

A good street lighting lantern is one which can be manufactured economically, is simple to install, and which will give an efficient and consistently good performance throughout life. The designer will strive for high efficiency; but this must not lead him to a product which is so critical that its performance depends on unreasonably precise manufacture or over-expensive maintenance. This article is concerned with factors which the designer must weigh in balancing good performance and economy.

INTRODUCTION.

THE design of a street lighting lantern is at once an optical and an engineering problem. Each aspect of the problem must be considered in relation to the other and in relation to such problems as convenience of handling, erection, relamping and maintenance.

A design must lend itself to large scale economic production. No matter how ingenious its optical design, a lantern will fail in its purpose if it is complicated and difficult to make. Equally, the lantern must give good service for many years. The need to design a good lantern which can be made within a given cost is both a stimulus and a discipline to the good designer; but it must not be made cheap by using inferior materials and workmanship. The contribution which the initial cost of the lantern makes to the annual cost of running an installation is often as small as 5 per cent and may even be as low as 3 per cent; but the cost of maintaining it may be three times as much; it is, therefore, quite uneconomic to install poor lanterns which produce a bad result or are exorbitantly costly to maintain.

In this article it is assumed that the designer wishes to secure a given light distribution with only a small tolerance both between new samples and for a given sample in service. Typical techniques and materials are described together with some of the more interesting problems which the designer is likely to encounter.

1. OPTICAL SYSTEMS.

(*a*) A PRIMARY WITH A SIMPLE SECONDARY OPTICAL SYSTEM.

Most lanterns use both refractor and reflector systems. Generally one system forms the primary and the other the secondary optical system. The primary optical system is defined here as the main light-controlling device in the lantern, whereas the secondary system may do no more than fill up small deficiencies in the main light distribution. Sometimes the secondary system comprises merely a white painted area or a simple, small reflector above the lamp to direct light downwards rather than allow it to be lost in the top of the lantern. Its effect on the lantern performance, in relation to an installation, is usually small, but it helps to maintain a high light output ratio and may help to enhance the cheerful appearance which is a characteristic of most good installations. Fig. 1(a) shows a section through a lantern for a high-pressure mercury vapour lamp in which the primary optical system is a refractor. It is in three parts, a refractor plate in each side of the lantern and a refractor trough in the bottom which opens for relamping. The secondary reflector system is relatively unimportant; it redirects, through the refractor, some of the upward light from the lamp that would otherwise be lost in the canopy.

In fig. 1(b) the primary optical system is a reflector. The secondary system, the ' rimpled ' globe, is a diffusing refractor: this is, once again, relatively unimportant, serving to diffuse the main beam slightly to prevent striations and to conceal the interior. Note that in these two examples the removal of the secondary optical components would not affect the light distribution seriously; though they are worth having, particularly the second which greatly improves the appearance.

(*b*) MULTIPLE CONTROLLING OPTICAL SYSTEMS.

In some lanterns two optical components play equally important parts. For example in fig. 2 a reflector and a refractor co-operate ' in series '. This system tends to be critical, a disadvantage

discussed more fully in Section 6(a) and to produce a rather low overall efficiency because of the many surface losses.

Refractors may also be used ' in series ', a common example being one in which an inner bowl or dome has substantially horizontal prisms to control light in vertical planes, and an outer bowl with vertical prisms controlling light in horizontal planes.

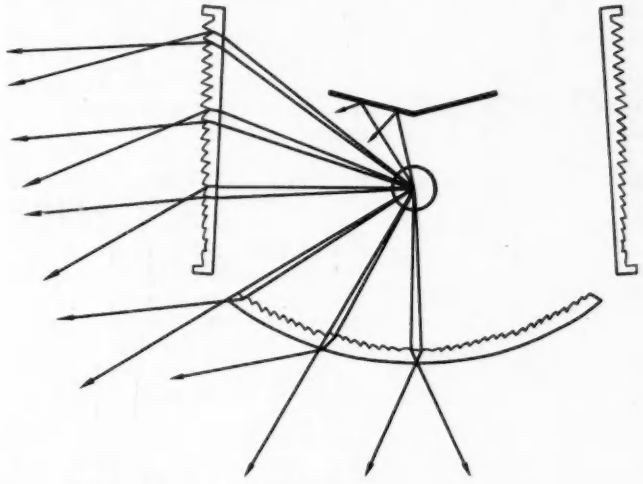


Fig. 1.—Optical systems for lanterns using horizontally burning H.P.M.V. lamps.
(a) (*above*).—Refracting primary optical system: Specular reflecting secondary optical system.
(b) (*right*).—Reflecting primary optical system: Diffusing refractor secondary optical system.

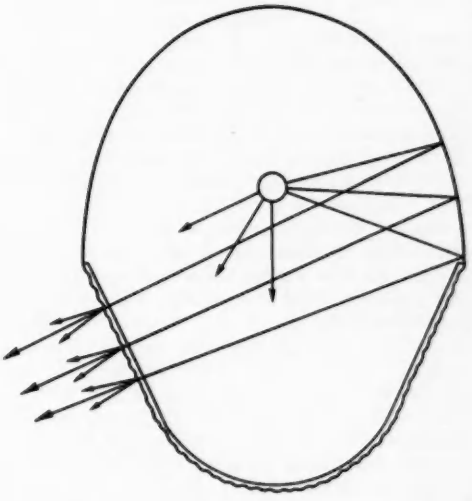
Two main components may also co-operate ' in parallel '. Where these components are both refractors the concept of the design is almost invariably that of a single optical system, split for mechanical convenience. For example, in the design of fig. 1(a) the redistribution of light effected by each prism element changes in an orderly and progressive way around the lantern. There is an obvious unity of design and the optical system is, therefore, classified as a single primary system even though three pieces of glassware are used in its fulfilment.

Where a combination of reflector and refractor is used ' in parallel ', however, each playing an important part, the system cannot be regarded as a simple primary one (fig. 3). Such a system tends to have a higher efficiency than the ' in series ' system and to be less critical.

Not all lanterns can be clearly classified in this way, but the majority fall in one or other category. Most are of the type described under (a). In general the designer prefers to use an ' optikon ',* the basis of which is the single primary and simple secondary optical system, for this tends to lead to a simple mechanical design. Occasionally, however, he will prefer the more complex multiple systems to meet a specific requirement. When this is necessary the multiple optical components are sometimes combined to form effectively a single physical component; for example the familiar " double bowl " arrangement in which the prisms are sealed against dirt and the outer surfaces are smooth, and, therefore, easily cleaned.

2. REFRACTOR AND REFLECTOR SYSTEMS COMPARED.

The designer of a new lantern must first decide whether to use refractors or reflectors for the primary optical system. A consideration of the light distribution required may immediately settle the matter. For example, a " cut-off " distribution in which the maximum intensity is required at 70° to the downward vertical with a negligible amount of light at 80° and above,



* The physical embodiment of the various reflecting or refracting devices in a lantern is called the " optikon " and generally speaking, therefore, a lantern consists of a canopy or body and an " optikon ".

calls for a reflector system of the type shown in fig. 1(b). To achieve the required cut-off with a refractor system would entail the use of large opaque screens outside the optikon, or expensive and complicated louvres. But a light distribution of the non-cut-off type in which the maximum intensity is at about 80° to the downward

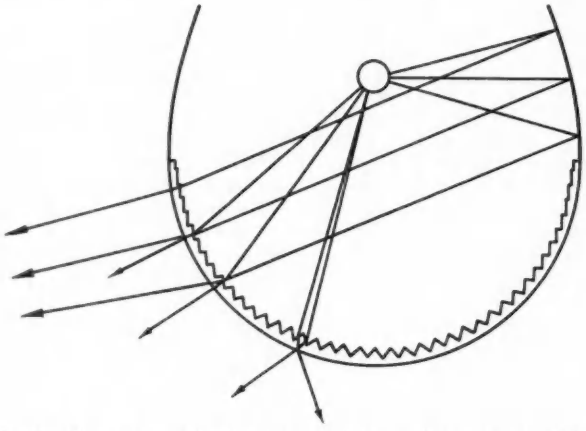


Fig. 2.—Optical system for lantern using horizontally burning H.P.M.V. lamp. Reflector and refractor co-operating ' in series '.

vertical, and in which there is no limitation on the amount of light at higher angles, may be achieved with a refractor system (for example, the type shown in fig. 1(a); with a reflector system; or with the dual system shown in fig. 3. With most non-cut-off distributions the designer has this wide choice. The fact that there are good examples of both reflector and refractor systems on the market shows that the choice is not obvious.

The relative merits of refractors and reflectors may be briefly summarised as follows:

(1) The materials available for refractors are extremely stable and have, therefore, an excellent life. The materials available for reflectors are less stable but the necessary life can be achieved if adequate precautions are taken.

(2) A refracting system is less critical than a reflecting system,* therefore manufacturing errors in lanterns using refractors are rather less serious than in lanterns using reflectors. In addition, refractors can generally be made more accurately than reflectors.

(3) A reflecting optical system, particularly in a multilamp non-cut-off lantern, may give a high light output ratio, but this is often obtained at the expense of accurate control of the light, some of which is wasted in directions where it is not required.

(4) The shape of a reflecting surface is determined by the light distribution required.

The designer will also be influenced by many other factors including the size of lantern; whether it is to be open or enclosed, the availability and cost of materials, the temperatures at which they will operate, the extent of protection required and the maintenance that can reasonably be expected. He will consider, in particular, the critical nature of the optical system he has in mind. A complicated design using many components and comprising primary, secondary and tertiary optical systems is a designer's daydream and has little place in practical optikons for street lighting lanterns.

A survey of non-cut-off lanterns made by the leading manufacturers shows that a refractor type of primary optical system is favoured for single lamp lanterns while the majority of multilamp fittings are of the reflector type. The G.E.C. lantern for three 80 watt fluorescent tubes shown in fig. 4 is a conspicuous exception

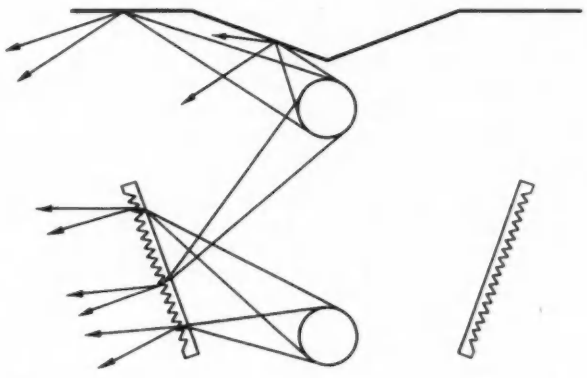


Fig. 3.—Optical system for lantern using tubular fluorescent lamps. Reflector and refractor co-operating ' in parallel '.

* An angular error of 1° in a reflecting surface will produce an error of 2° in the reflected ray: a similar error in a refracting surface will generally produce an error of less than 1° in the refracted ray.

using a complex primary (refractor) optical system and a simple reflecting type of secondary system.

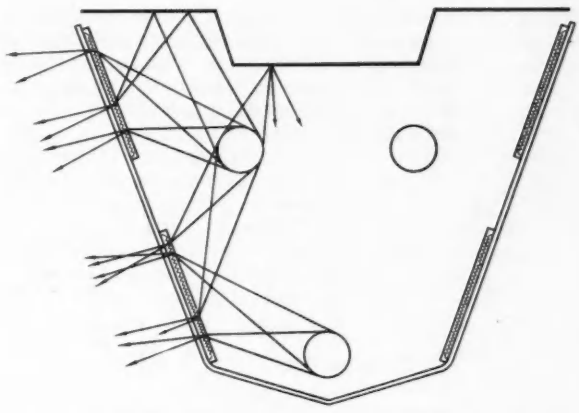


Fig. 4.—Optical system for lantern using tubular fluorescent tubes. Complex primary refracting optical system: specular reflecting secondary optical system.

3. CHOICE OF MATERIALS FOR THE OPTIKON.

(*a*) REFLECTORS.

The materials available for specular reflectors for street lighting lanterns are well known. Briefly, the most commonly used are as follows:

(*i*) *Glass.* This may be formed by blowing, pressing or drooping before it is silvered: it may be clear or diffusing. The silvering must be protected, for example, by lead backing.

(*ii*) *Metals.* Those most commonly used are aluminium brightened and anodised; and highly polished stainless steel. They may be formed by bending, rolling, spinning or pressing. Where a highly diffusing reflector is required it is common to use white vitreous enamel or good quality stoving enamel.

(*b*) REFRACTORS.

Only two materials are commonly used for refractors in street lighting lanterns: these are glass and " Perspex ".*

(*i*) Glass refractors are normally formed by pressing, but where high accuracy is not required prismatic glass sheet and figured diffusing surfaces are produced by rolling.

The choice of glass to be used for a pressed prismatic refractor depends almost entirely on the thermal shock to which it may be subjected in service, and the accuracy with which it needs to be made. The temperature of the outside surface of the refractor of an enclosed lantern using a high wattage lamp may be as high as 120 degs. C.: if this is to withstand rainsplash a glass of low thermal expansion, e.g. a borosilicate glass, must be used. In some lanterns using high wattage lamps, the temperature gradient produced in the refractor merely by switching on the lamp may be sufficient to cause failure if a suitable heat-resisting glass is not used.

To some extent the harder glasses with a shorter working range* and a tendency to chill more rapidly from the softening temperature, produce more accurate prismatic formations than soft glass.

Unfortunately, the hard glasses have to be pressed at much higher temperatures than soft glasses; this increases the cost of melting as well as causing increased wear on the moulds which are expensive. Obviously, therefore, the glass should be sufficiently hard for the purpose but should not provide an extravagant margin of safety.

Glass is a relatively variable product, since so many factors can affect its performance. Therefore, in the cost of production must be included the cost of a stringent schedule of testing.

(*ii*) " Perspex " has optical properties similar to those of soft glass. It is commonly formed into prismatic refractors by two methods: shock moulding and machining.

In the shock moulding process a sheet of " Perspex " is first softened by heating to about 170 degs. C. and then formed into the required shape under a pressure of 2 to 3 tons per sq. inch. The tool costs are high and a refractor plate measuring about 5 in. by 10 in. requires a 100 or 150 ton press.

Machined refractors are produced by cutting the prisms in a flat sheet with a ganged milling cutter in a single cutting operation. The cutter runs at high speed and a suitable coolant is used. In this way, long lengths of refractor plate may be produced from flat sheet of thickness $\frac{1}{8}$ in. to $\frac{3}{8}$ in. depending on the prismatic design. The cost of the tool is considerably less than that of the die for shock moulded plates,

* Trade name for polymethyl methacrylate plastic made by I.C.I.

* Working range: range of temperature over which the glass can be moulded.

but the relatively poor surface finish demands that the plate be polished after machining. This is done by spraying the plate with a suitable solvent and allowing it to dry quickly in warm air. Considerable skill is required to obtain a sufficient polish without the attendant risk of subsequent " crazing ". It is not possible to remove the tool marks entirely, but plates polished in this way are likely to be better than shock moulded plates, and are, in fact, perfectly good for the job.

Optical components blown or moulded from flat " Perspex " sheet tend to return to the flat sheet if the temperature is raised above the softening point (about 100-110 degs. C). The higher the temperature the more rapid is the deformation and the safe operating temperature for blown or moulded articles, which must retain their shape for long periods, is normally taken to be 70-75 degs. C. This " elastic memory " is characteristic of shock moulded plates but is completely absent in plates machined from flat sheet which, theoretically at least, can be used at higher temperatures.

(*c*) Transparent Enclosures.

In some lanterns the refractor itself may form the enclosure for the lamp and with the canopy a totally enclosed lantern is obtained. In other designs the refractors and lamp are enclosed by a transparent cover which may be clear or may have a diffuse or prismatic surface.

Transparent enclosures may be made in glass or " Perspex " and may consist of bowls, dishes, or simple bends cemented into a glazing frame. " Perspex " bowls and dishes are formed by heating flat sheet to about 150 degs. C and sucking it by vacuum through an aperture of the required shape : the final shape of the article is often produced by forcing a forming tool on to the half-moulded material. The process is economical since the " Perspex " stretches during moulding so that bowls and dishes with quite thin walls may be produced. Moulded enclosures must not be subjected to temperatures above 70-75 degs. C.

Glass enclosures are produced by blowing, pressing and drooping. The shape of blown articles is determined by the mould which surrounds the glass " bubble " in the last stage of the process. Pressed glass enclosures are produced in much the same way as glass refractors, with a plunger and mould: they tend to be thick and heavy, are subject to the same limitations as glass refractors, and are not commonly used. Blown and drooped glass bowls are usually quite thin and light and when made in suitable heat resisting glass will withstand the highest temperatures likely to be met in street lighting lanterns.

4. Relative Merits of Glass and Plastics.

Glass and " Perspex " are to some extent rivals in the same field. However, although the introduction of " Perspex " has led to designs which would not have been possible in glass, each material has its own place in design and, in particular, glass must be used where the lantern operates at a high temperature. The other important advantage of glass is its good abrasion resistance: its main disadvantages are its fragility and its weight. " Perspex " has only moderate abrasion resistance: its main advantages are its lightness and resilience, its resistance to thermal shock and the ease with which it can be formed and fabricated.

5. The Lantern Body.

(*a*) Materials for the Canopy.

One of the best materials for the body of a small lantern is silicon-aluminium alloy, since it can be die-cast with a high repetitional accuracy which obviates machining. In addition, it has an inherently high resistance to corrosion. Cast iron is still used in some lanterns and sheet metal constructions are commonly used in large fluorescent fittings. Plastics are not greatly used but there are already a few good lanterns on the market with canopies and optikons made almost entirely of " Perspex ". Its resistance to weathering is extremely good though its temperature limitations and cost restrict its use considerably. Other plastic materials have been considered from time to time but none of them, so far, has exhibited all the essential requirements simultaneously, i.e. reasonable temperature characteristic, reasonable cost and high resistance to corrosion or weather.

(*b*) Metal Components.

The materials used for auxiliary components such as screws, hinge pins, toggle catches and retaining rings, must be considered in relation to the type of protection which they may have e.g. cadmium plating or galvanising: as well as to the material to which they will be fixed. For example, brass or copper components should not be in contact with aluminium alloys since the electrolytic action set up between them in the presence of moisture causes rapid corrosion.

Many special alloys have been tried; some are successful, all are relatively expensive: but the extra cost of using a really reliable material is almost insignificant compared with the expense involved either in replacing a faulty component

or in over-frequent maintenance. A very reliable material is good quality stainless steel: its extra cost is more than offset by the freedom from trouble which it ensures.

(*e*) GASKETS.

Totally enclosed lanterns are usually opened for relamping and cleaning by releasing one or two simple toggle catches and allowing a part of the lantern to swing downwards on hinges. The joint between these two parts must form a reliable weather-tight seal and, where a part of the optikon is carried in the lower part of the lantern, the joint must maintain its dimensions within reasonable limits. It is impracticable to prevent the lantern "breathing" due to the large changes in temperatures inside the lantern, when the lamp is switched on and off. The joint must, however, prevent rainwater entering the lantern directly even in the worst conditions of horizontal driving rain and high winds.

The simplest and most reliable way of achieving this is to arrange for an adequately deep shroud to cover the joint or for the joint itself to be so designed that rainwater must run up a riser of about $\frac{1}{4}$ in. before entering the lantern. The hinges and toggles, etc. must not interfere with the continuity of the joint around the lantern. Such a device, well designed, can keep water out without any gasket; the addition of a gasket, however, is normally required to keep out insects and to increase the overall effectiveness of the joint.

Sometimes the gasket is required to prevent without assistance the ingress of rain. In such cases water may be prevented from entering the lantern by a riser formed in the upper side of the gasket. The gasket is cemented to the lower component with an adhesive which must ensure a water-tight seal between the gasket and the component.

The choice of material for a gasket varies considerably according to the conditions which it must satisfy. A good quality felt gasket may be a sufficient barrier to insects but because it is porous it will not prevent the direct entry of water. Felt materials are generally suitable for high temperature conditions though they tend to harden and shrink with age. Natural and synthetic rubbers are frequently used for gaskets, the resilience and elasticity of rubber being better than that of any substitute. Rubber can be moulded and extruded, and can, with suitable "fillers" and treatment, be supplied in a wide range of hardnesses. It can also be "aerated" to make it soft and spongy. It is reasonably cheap, but it has two considerable disadvantages, namely, a poor ozone resistance and a relatively poor thermal resistance. The highest temperature which ordinary rubber will withstand is about 70 degs. C. Special heat-resisting rubbers will withstand temperatures as high as 100 degs. C, but are more expensive than ordinary rubber. Heat hardens and cracks rubber, the effects being accelerated as the temperature increases.

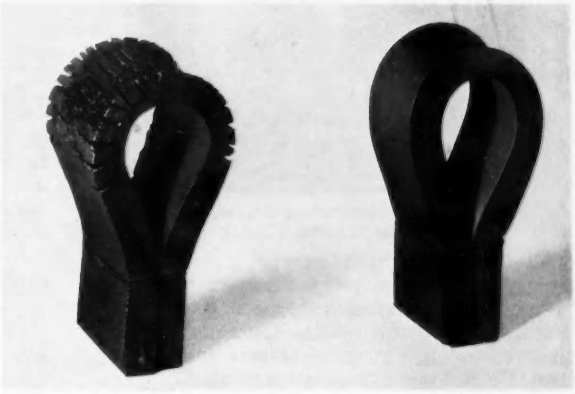


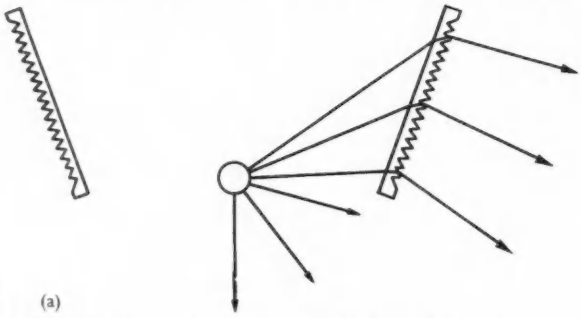
Fig. 5.—Rubber samples after exposure to a high concentration of ozone.
(a) (*left*).—Natural rubber after $3\frac{1}{2}$ hours.
(b) (*right*).—Butyl rubber after 14 hours.

The small concentrations of ozone in the atmosphere are sufficient to attack rubber which is exposed to the weather. The attack is quite rapid on surfaces which are in tension, but much less severe on surfaces which are unstrained or in compression. The attack takes the form of many small fissures running from the surface into the depth of the material, gradually becoming deeper and larger until the tensile stresses in the material have been eliminated. In practice this usually results in complete failure. If a straight piece of rubber is bent and exposed to ozone attack it cracks on the tension side so that the neutral axis gradually retreats towards the compression side of the material, allowing fibres, originally unstressed or in compression, to be brought into tension and exposed one by one so that they crack progressively. Fig. 5(a) shows this effect on a sample of natural rubber, after being exposed to a high concentration of ozone for $3\frac{1}{2}$ hours. A similar sample exposed for 7 hours failed completely. The photograph shows

Fig. 6.—Optikon for vertical burning H.P.M.V. lamp. One-piece primary refractor.

clearly that the extent of the damage is greatest where the tensile stress in the material is greatest and negligible where there is no stress. The underside of this sample (the part in compression) showed no signs of attack at all.

Fig. 5(b) shows a similar sample of Butyl rubber exposed to the same concentration of ozone for 14 hours: it has not suffered in any way. This material is often better than natural rubber where it is to be exposed to the weather.



(a)

Fig. 7.—Optical systems for lanterns using horizontally burning sources.
(a) Two-part refracting primary optical system.
(b) Two-part reflecting primary optical system.

With suitable "fillers" it will withstand a temperature of 120 degs. C. and is available in a wide range of hardnesses. Its disadvantages are that it is difficult to extrude, moderately difficult to mould, and is rather more expensive than ordinary rubber. At best it is never quite so resilient as rubber and its compression set* characteristics are not so good. It can, however, be used with confidence where the loading conditions are not severe which is usually true in street lighting fittings.

Silicone rubber is the only resilient material which will withstand very high temperatures. Unfortunately, it is expensive, not so resilient as rubber and rather more difficult to extrude. Its cost practically rules out its use in street lighting lanterns except possibly for small components.

* Compression set: the permanent deformation with age suffered by rubber under load.

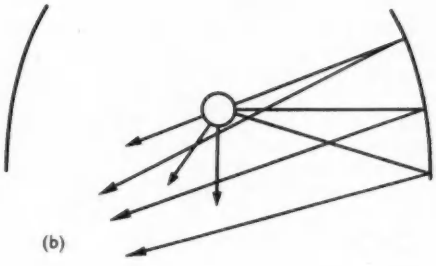
6. GENERAL CONSIDERATIONS.

Many detailed problems which arise in the design of a street lighting lantern have now been considered, but other, broader, issues remain. It will be convenient to discuss some of these under four headings, although since they are closely related it is not possible to avoid a certain amount of overlapping.

(*a*) The critical nature of the optical system.
(*b*) Efficiency: high light output ratio and good light distribution.
(*c*) Accuracy and simplicity.
(*d*) Effect of light distribution required.

(*a*) Critical Nature of the Optical System.

A lantern cannot be made precisely to the objective dimensions. The manufacturer must be allowed reasonable tolerances in the individual components and in their assembly, and the designer must ensure that his design is sufficiently non-critical for these tolerances not to affect the performance of the lantern seriously. A non-critical optikon is the first essential: and, for a given size of lantern, this is most easily achieved with a single one-piece refracting optical system and nothing else. The pressed glass bowl shown in fig. 6 is a good example. The refractor is non-critical, and since it is pressed in glass the location of the prisms in relation to each other is very accurate. All that is required for a satisfactory performance from an optikon of this type is



(b)

that the lamp should be correctly positioned in the bowl.

Fig. 7(a) shows another non-critical optical system consisting of two refractor plates, one on each side of the lamp. The plates must be located correctly in relation to each other and in relation to the lamp; thus it is only one stage removed from the ideal.

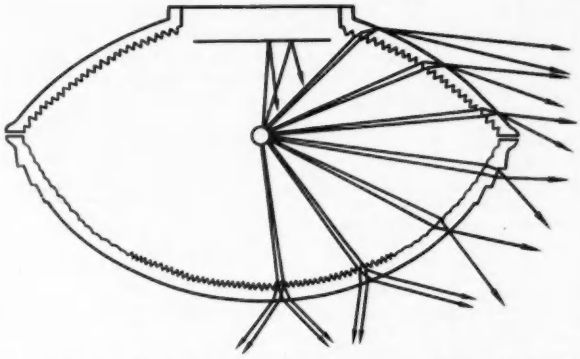


Fig. 8.—Optical system for lantern using horizontally burning source. Two-part refracting primary optical system.

Fig. 7(b) shows a reflector type of optical system which promises to give the same sort of performance as that of fig. 7(a). But, since reflectors are more critical than refractors, for the same general dimensional tolerances this arrangement will give a less consistent performance. Alternatively, a higher accuracy of manufacture will be required to obtain the same consistency.

Another aspect of the problem is found in optical systems where two or more optical components " mate " to produce the required light distribution. Fig. 8 shows an example of a two-part refractor system and fig. 9(a) the light distribution which it produces.

This distribution may be obtained in various ways depending on the contribution from each refractor. For example, the upper refractor may be responsible for the upper part of the beam and the bottom refractor for the lower part of the beam with little overlap between the two (fig. 9(b)). Alternatively, the distribution may be obtained from two contributions of rather different shape and overlapping considerably (fig. 9(c)). This latter arrangement is much less critical since small errors in location of the two refractors and therefore of the overlap between the two contributions will produce only small changes in the final distribution. The arrangement shown in fig. 9(b) is very critical because of the " scissor action " between the two individual contributions; a small displacement of the upper refractor relative to the lower will produce large changes in the shape of the resultant distribution.

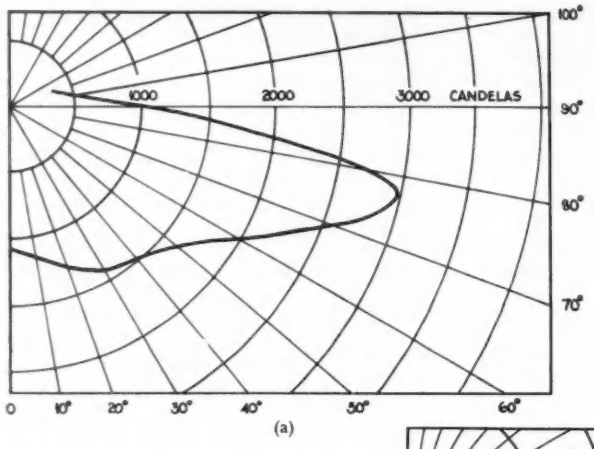
Similar considerations apply where the required distribution is obtained by a contribution from an optical component and from a bare lamp, for example, fig. 7(a). Once again, these should " mate " so that the resultant is reasonably non-critical. A good rule is that the bare lamp and the optical component should both contribute in the direction of maximum intensity, and, if possible, each should produce its maximum in that direction.

(*b*) Efficiency.

A lantern must utilise the light from the lamp to the best advantage, i.e. a high light output ratio with a good light distribution is required. A satisfactory distribution of light may be obtained from a wide variety of optical systems, of which those shown in figs. 6, 7 and 8 are examples. But a high light output ratio can rarely be achieved from such simple arrangements without introducing secondary and sometimes tertiary optical components. The introduction of the secondary optical system requires considerable ingenuity and restraint on the part of the designer. The more important the part played by the secondary system the less sensitive to dimensional tolerances must it be.

Fig. 10(a) shows the two-part refractor system with the addition of a diffuse white reflector above the lamp forming the secondary optical system. Although it is relatively large, it is quite insensitive to dimensional errors and its exact shape is also unimportant. The result is a very satisfactory non-critical optikon which allows reasonable tolerances in manufacture, and which can be relied upon to give consistent results.

Fig. 10(b) shows the reflector system with the addition of a large curved specular reflector above the lamp. This secondary optical component co-operates with the primary reflector to redirect light into regions just below the main beam. It is an extremely critical arrangement in which small errors in either reflector, particularly the secondary, are likely to produce large errors in the performance of the secondary optical system. It is a nice design on paper but impracticable unless it can be manufactured with high accuracy.



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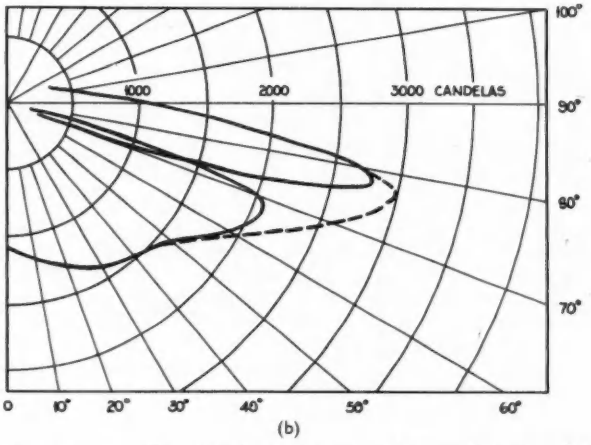


(b)

Fig. 9.—Light distribution from components of optical system shown in fig. 8.
(a) Distribution from complete optikon.
(b) Distributions from individual components showing little overlap.
(c) (*top of facing page*).—Distribution from individual components showing considerable overlap.

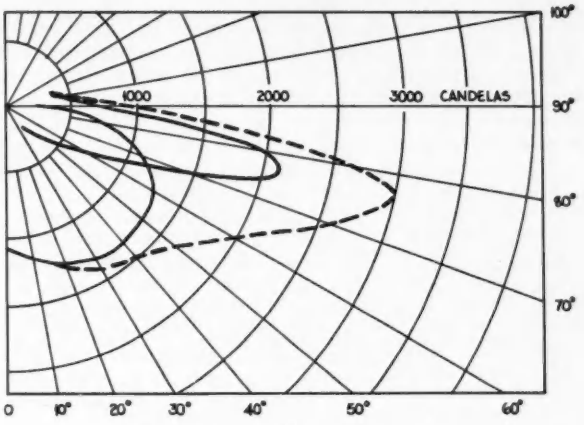
The greater the part played by the primary optical system and the less important the secondary system the more satisfactory will be the result. The designer will generally try to achieve the best possible performance from his primary system so that he has to use only a relatively unimportant secondary system, for the "finishing touch". It is no accident that most of the good lanterns on the market to-day conform to this principle.

(c) Accuracy and Simplicity.

The accuracy of location of the optical components in relation to each other and in relation to the lamp determines how nearly the performance of the lantern approaches the objective. A relatively critical optikon will require a high accuracy of manufacture and vice-versa.

In the ideal optikon, consisting of a single optical component with the lamp mounted directly on it, only the tolerances in the lamp, the lampholder and the lampholder location and in the optical part itself contribute to the overall error. This simplicity is rarely achieved in practice for a number of reasons. For example, it is not usually possible to manufacture the optikon in one piece and it is impractical to screw a lampholder on to a glass refractor. The method of opening the lantern and the convenience of relamping usually prevent the best arrangement optically from being the simplest mechanically, and a sensible compromise has to be adopted. The compromise varies considerably for different types of lantern.

Fig. 11 shows an open lantern for use with 45 watt and 60 watt sodium lamps. The optikon comprises a simple primary refractor optical system and the simplest secondary reflector system (white paint). The lampholder is mounted in the "Perspex" canopy to which the refractor plates are cemented. The tolerances contributing to the overall tolerance of location of the lamp with respect to the refractors are due to the lamp, lampholder, lampholder location in bowl, bowl itself, and the location of the refractors in the bowl—five items in all. This is a simple arrangement and has much to commend it; but in the enclosed lantern for use with the same lamps (fig. 12), it is not convenient to mount the lampholder in the bowl. Instead, it is supported from the metal canopy by means of a bracket and the bowl itself is clamped up to a soft rubber gasket in the underside of the canopy. The accuracy of location of the lamp relative to the refractors is now determined by tolerances



(c)

in the following items: lamp, lampholder, lampholder location on bracket, bracket, bracket location on canopy, gasket location on canopy, gasket, bowl and location of refractors in the bowl—nine in all.

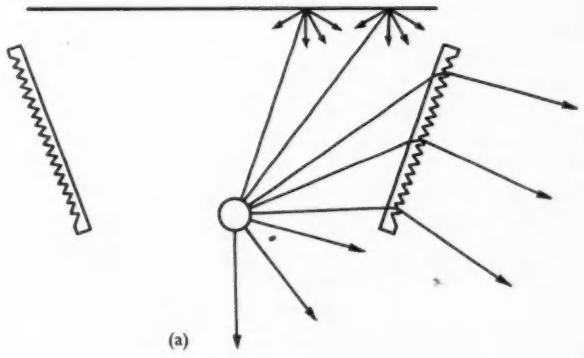
In both these lanterns a similar analysis may be made in regard to the lamp steady which supports the lamp near the end remote from the lampholder. It will be found that similar tolerances apply to the location of each end of the lamp but that to some extent they are independent of each other. This is, in a sense, fortunate, since otherwise the errors would always move together in the same direction and the centre of the lamp would be as much displaced from its objective position as either of its ends. As it is the error in location of the centre of the lamp is never as great as that of either of its ends: the lamp will usually be slightly tilted, but this is not significant.

The accuracy of location of the lamp in the optikon, as has been seen, may be determined by many different items; fortunately, in practice, most of the components can be made and located with considerable precision. In addition the variations in the individual components do not add up directly but at random. For example, the overall tolerance of 4 items each with $\frac{1}{16}$ in. tolerance is not $\frac{1}{4}$ in. but $\frac{1}{8}$ in. (i.e. $\sqrt{4 \times (\frac{1}{16})^2}$ on the same basis.* The good repetitional accuracy of die castings and refractors has already been mentioned and such items as lampholder brackets and steadies may be made in accurate jigs. An occasional check on jigs and dies will ensure that the components are made to the required standard.

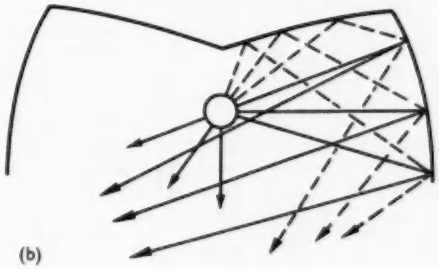
It is clear, however, that the number of components should be kept to a minimum consistent with manufacturing techniques and cost. Simplicity in design and manufacture will greatly assist in the repetitional accuracy of the final product.

Once a lantern has been installed there are, apart from keeping it clean, two groups of factors to consider when assessing its performance.

* A reasonable basis is that not more than 1 in 20 samples should fall outside the stated tolerance. If this were the basis in the example quoted the combined tolerance of $\frac{1}{8}$ in. would also occur not more than 1 in 20 times. The chance of getting an overall error of $\frac{1}{4}$ in. (i.e. 4 times $\frac{1}{16}$ in.) is 1 in 20^4.



(a)



(b)

Fig. 10.—Optical systems for lanterns using horizontally burning sources. Compare with fig. 7.

(a) Two-part refracting primary optical system and diffuse reflecting secondary optical system.

(b) Two-part reflecting primary optical system and specular reflecting secondary optical system.

First, there are permanent errors in the lantern due to manufacturing tolerances: and second, there are variations associated with the performance of the lamps. The light output of the lamps varies throughout the life of the lantern. In addition, variation in light centre length* may cause a variation in light distribution each time the lantern is relamped. For H.P.M.V., sodium and fluorescent lamps, in which the length of the source is large compared with the light centre length tolerance, the effect is negligible; but with tungsten lamps a significant variation in distribution can occur. It is particularly important, therefore, that where tungsten lamps are used the permanent errors in the lantern should be small so that variations in distributions are centred on the objective.

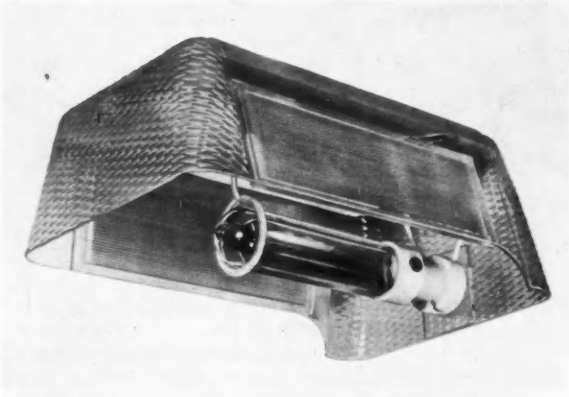


Fig. 11.—Open lantern for small sodium lamps. "Perspex" optikon with lampholder mounted directly on it.

(*d*) EFFECT OF LIGHT DISTRIBUTION REQUIRED.

The factors so far outlined must be considered in relation to the light distribution required.

In the high angle beam distribution the shape and the exact direction of the maximum intensity are relatively unimportant. Medium angle and cut-off distributions, however, are more critical, the direction of the peak must be maintained within a few degrees, and the intensity must fall off fairly rapidly above the peak. The accuracy and consistency with which such distributions are repeated from lantern to lantern may considerably affect the overall performance of the installation. Non-critical distributions do not require the same accuracy of design and manufacture as critical distributions.

* Axiality errors should strictly be included.

7. CONCLUSION.

A designer, when considering a new lantern to meet some particular requirement, will not consciously weigh up all the various factors one by one. He will know, as a result of experience, what materials are likely to be suitable and what type of optical system is likely to do the job. For example, he is unlikely to consider "Perspex" where high wattage H.P.M.V. lamps are to be used or to consider a refractor system where a cut-off distribution is required. His experience gives him something approaching an instinct in the matter; he will quickly discard the impossible for the possible and then consider the various compromises, bearing in mind that the final product must lend itself to large-scale economic production, must perform with accuracy and consistency over a long period and must be simple to erect and maintain.

Designing is an art as well as a science. Occasionally a lantern will break all accepted rules and yet be successful, and often such a lantern marks an important step forward and sets the pattern for progress. Nevertheless, it is always wise to test such an unorthodox design by accepted good standards to make sure that it is not merely the result of haphazard thinking.

Fig. 12.—Enclosed lantern for small sodium lamps. "Perspex" optikon with lampholder mounted from metal canopy.

TECHNICAL LITERATURE

A DIGEST OF RECENT BOOKS, ARTICLES AND PAPERS, BY MEMBERS OF THE G.E.C. AND ITS ASSOCIATED COMPANIES

WOODS' PRACTICAL GUIDE TO FAN ENGINEERING

Woods of Colchester Ltd., Colchester. 227 *pp.* 10s. 6*d.*

This treatise covers the basic principles of fan engineering comprehensively and in a form that is easily assimilated. It is essentially a practical working guide which deals both with fans, their associated problems and their many applications. Much information is included in quick-reference form and the nineteen sections cover a quantity of data not hitherto available in the compass of one volume. The book contains 143 diagrams and illustrations, 61 tables and 33 charts and should be equally valuable to the student, the designer and the practical engineer.

PROCEEDINGS I.E.E., Vol. 99. Part III (a)—1952.

DESIGN FACTORS IN TELEVISION CATHODE RAY TUBES (500)

By L. S. Allard (Research Laboratories).

The paper discusses the general trend in tube size for directly viewed television tubes, and considers the merits of both metal tubes and "all-glass" tubes. The alternative method of producing large pictures, namely by projection, is considered, and the techniques by which the form of receiver might be improved are given. The various types of focusing employed for television tubes are discussed, and the reasons are given for the choice of electromagnetic deflection.

The "electron-optics" of the gun are considered in detail, indicating the method by which the existing compromise has been obtained. The theory outlined refers both to directly viewed tubes and projection tubes. Improvements in the performance of both types of tube could be achieved by the use of higher screen efficiencies, cathodes capable of withstanding higher loadings, and by a reduction in the spot-swelling characteristics of the electron gun.

GROUP DELAY MEASURING EQUIPMENT (501)*

By G. J. Hunt and L. G. Kemp (Research Laboratories).

The paper describes equipment used to measure changes in the slope of the phase/frequency characteristic of a transmission system over a frequency range extending from 200 kc/s to 5 Mc/s. The equipment can be used equally well for the measurement of a system of which the input and output terminals are available in one place, or under the conditions common in an installed system with remote transmitting and receiving terminals.

When the transmitter test frequency is varied from a datum frequency over the range desired, direct readings of group delay distortion are given by a cathode ray tube display calibrated in intervals of 10 milli-microseconds.

A brief reference to this equipment was made in a recent paper on the London-Birmingham Television Radio Relay Link.

APPARATUS FOR THE MEASUREMENT OF NON-LINEARITY IN TELEVISION TRUNK SYSTEMS (502)*

By G. W. S. Griffith (Telephone Works, Coventry).

The paper describes the normal methods of measuring non-linearity, using saw-tooth and staircase waveforms, and outlines their shortcomings.

Two systems that overcome these difficulties are described and their uses compared, with particular reference to television-type waveforms (containing a D.C. component).

Reference is made to that particular form of non-linearity in which the ratio of a synchronising signal to picture signal is altered by the transmission system.

ON OVERCOMING THE NON-INTERLACING OF TELEVISION RECEIVERS WHICH ARE ACCURATELY SYNCHRONISED (503)*

By G. B. Townsend (Research Laboratories).

Many domestic television receivers do not interlace correctly even when the frame flyback is being initiated at the correct time. The principal causes of this effect are variations in the amplitude of the frame flyback. The mechanisms of such variations have been investigated and means of reducing the variations are detailed. In particular the design of the oscillator stage, which is at least as critical for good interlacing as the design of the synchronising separator, is discussed.

Despite the presence of most of the variations referred to, it is practicable to maintain the flyback amplitude constant by a method which is applicable to the majority of domestic receivers.

A WAVEFORM GENERATOR AND DISPLAY UNIT FOR THE TESTING OF A TELEVISION CHANNEL (504)*

By P. E. Ackland-Snow, and G. A. Gledhill (Research Laboratories).

In certain respects the transmission characteristics of a communication channel designed for television service differ somewhat from those of a channel designed for telephony. Such differences entail measurement of parameters not adequately covered by the usual transmission measurements.

This paper is intended to indicate the manner in which the problem has been at least partially solved by providing special test apparatus utilising television-type waveforms.

U.H.F. SWITCHES AND FILTERS (505)*

By G. F. Small (Research Laboratories).

The paper discusses the uses of filters and switches in u.h.f. radio-relay links. Typical requirements for such components are given and possible designs reviewed.

As examples, designs of filters and switches used in the London-Birmingham Television Radio-Relay Link are given in detail. The switch employs resonant stub lines placed in shunt with the main transmission lines; typical performance details are given. The filters are of the band-rejection type, and consist of stub lines, composed of a series of nominal quarter-wavelength sections of line, shunted across the main transmission line. Design curves for the filter stubs and complete filters are given. Typical filter attenuation curves are shown and comparison between the theoretical and experimental results is made.

THE LIFE TESTING OF CATHODE RAY TUBES (506)*

By R. C. Hart (Research Laboratories).

The principal requirement of cathode ray tube life-testing equipment is that it shall give an accurate description of the life performance of any type of cathode ray tube in the shortest time possible. The attainment of this object is achieved only after due consideration of all the factors involved, which include the safety of personnel from electric shock and mechanical implosion, the flexibility and reliability of apparatus, and methods of arriving at an estimate of life before failure actually occurs.

The paper describes how the problem has been approached and concludes that the desired flexibility in the apparatus can best be achieved in an open bunch type of equipment. This entails the provision of electrical safeguards to protect the operator.

COLOUR AND TELEVISION: OBJECTIVE AND SUBJECTIVE ASPECTS (507)*

By G. T. Winch (Research Laboratories).

After a brief review of the literature on the more general aspects of colour in television, attention is drawn to the subjective aspects of picture quality, both in monochrome and coloured pictures. Reference is made to earlier work on a somewhat similar problem of colour-rendering in which the binocular matching technique has given promising results. Based on this experience, apparatus and methods are described which should facilitate the study of the subjective requirements under different conditions of presentation and view. These subjective requirements could then be related to the objective photometric and colorimetric measurements carried out by physical instruments indicating directly in the C.I.E. system. Reference is made to the interest shown by the C.I.E. in colour television and their 1951 resolutions on this subject are recorded.

THE MONOSCOPE (508)*

By R. D. Nixon (Research Laboratories).

The monoscope is an electronic device producing a television picture-signal by scanning with a focused beam of electrons, a picture whose secondary-emission ratio varies according to the brightness in the original scene. This variation may be achieved by printing with some form of carbon on a metal plate. The method described, employing light-sensitive fish-glue as the printing medium, in conjunction with fine half-tone screens, has been found to give superior results to direct or offset printing with inks. The use of silver as a base material, instead of the more commonly employed aluminium, results in picture reproductions free from spurious signals.

An electrostatically focused, magnetically deflected electron gun has been developed for television type monoscopes. The final anode voltage of 5 kV enables a sharply focused beam to be obtained.

The resolution of the tube is determined by the scanning spot size rather than by the definition of the picture plate, and is a maximum of about 1,000 lines at a signal output of 2·5 microamperes peak-to-peak.

THE PERFORMANCE OF TELEVISION RECEIVER INSTALLATIONS IN THE PRESENCE OF INTERFERENCE (509)*

By A. J. Biggs and R. A. Mills (Research Laboratories).

The television receiving installation is susceptible to interference by three processes which can broadly be classified as follows :

(*a*) pick up of interference by the aerial system ;

(*b*) direct pick up by the receiver circuits ; and

(*c*) mains-borne interference introduced by connection to supply.

Measurements are described which give the relative significance of these processes under typical operating conditions. The data provided on modern commercial receivers lead to the conclusion that the performance standards of the average receiver are satisfactory and that large strides to achieve immunity from interference do not involve radical development of received design.

DISCHARGE LAMPS IN TELEVISION STUDIOS (510)*

By E. H. Nelson and W. A. Price (Research Laboratories).

The use of discharge lamps for television studio lighting is discussed from the point of view of the lamp engineer. The special lighting problems associated with broadcast television are considered ; and various types of discharge lamp, potentially of use in television studios, are briefly discussed. Three lighting fittings designed for studio lighting are described.

PHOSPHORS FOR TELEVISION CATHODE RAY TUBES (511)*

By H. G. Jenkins, A. H. McKeag, and E. E. Welch (Research Laboratories).

This paper reviews the development and present position of television tube phosphors and screens. The theoretical aspect of luminescent emission is discussed and the limitations of the accepted theory indicated. The preparation of the chief television phosphors is described and their luminescent and other characteristics mentioned. The more important methods of making the television screen are given and the effect of voltage and current on the screen performance is discussed. Reference is made to a number of special matters such as secondary emission aluminised screens, screen colour and afterglow. A number of outstanding problems are indicated in a concluding section.

* A limited number of reprints is available of those papers marked with an asterisk. Copies may be obtained on application to the Editor, G.E.C. Journal, Magnet House, Kingsway, W.C.2.

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